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ADVANCED HYGIENE.

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ADVANCED HYGIENE.

FOR THE ADVANCED EXAMINATION OF THE BOARD OF EDUCATION.

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PREFACE.

The very favourable reception of First Stage Hygiene in this series by teachers and students, as well as the press, has induced the publishers and the authors of the present volume to think that there is an equal demand for a suitable book which represents a second years' course of study of Hygiene and Public Health. Most of the books already available for this purpose cover far more ground than the average student finds it possible to assimilate in one session, and, moreover, present such a wide course of study that most students find it quite impossible to devote sufficient time to it to acquire a practical as well as a theoretical knowledge of the subject.

The arrangement of the subject is similar to that of First Stage Hygiene, and, as far as possible, the different parts of the subject are taken in the same order. The lists of experiments that are added at the end of many of the chapters represent only the minimum amount of this kind of work, though they will doubtless suggest further possibilities in this direction. All the experiments described can be very easily carried out by the average student.

Chapters I., III., IV., IX., and XI., and the part of Chapter V., relating to Personal Hygiene and Disease, have been written by Mr. Lyster, while Mr. Ikin is responsible for Chapters II., VI., VII., VIII., X., and the remainder of Chapter V.

The authors will be very pleased to receive and to acknowledge any suggestions from teachers and students as to any means of adding to the usefulness of the book.

A. E. I.
R. A. L.

May, 1902.

TABLE OF CONTENTS.

CHAPTER IV.

ACCESSORY FOODS.

CHAPTER V.

PERSONAL HYGIENE—EXERCISE—HABITS.

CHAPTER VI.

THE DWELLING HOUSE.

CHAPTER VII.

HEATING.

CHAPTER VIII.

WATER-CLOSETS AND DRAINS.

CHAPTER IX.

REMOVAL AND TREATMENT OF REFUSE.

CHAPTER X.

WATER.

CHAPTER XI.

PREVENTABLE DISEASES.

ADVANCED HYGIENE.

CHAPTER I.

AIR.

The importance of a supply of pure air for all the rooms of a house is not yet realised by the public to the extent that it should be. In nearly all towns and villages there is a popular demand for a pure water supply, and yet the very people who will insist upon this are, in many cases, living year after year in rooms where the chimney is stopped up and the windows never opened. Children reared amidst such surroundings are liable to be rickety and tuberculous, and, even if they escape these diseases, their growth is stunted and their constitution permanently injured.

The relative importance of pure air to the body is easily understood when it is considered that there are cases on record of human beings living for five or six weeks without food, whereas deprivation of air causes death in four or five minutes.

Air is a mixture of gases in which each constituent preserves all its characteristic chemical and physical properties, the properties of air being a mean between the properties of its constituents. Its composition is not invariable. If air were a chemical compound its composition would be invariable, and its properties would bear no relation to the properties of its constituents.

The **average volumetric composition** of pure atmospheric air may be taken as

Nitrogen	78
Argon	1
Oxygen	20·96
Carbon dioxide	·04
	100·00

There are also variable quantities of water vapour, ammonia, organic matter, mineral salts, nitric acid, and traces of ozone; in towns sulphurous acid and sulphuretted hydrogen are present.

It is a remarkable fact that the composition of the air is practically the same in every part of the world. In mid-ocean it differs but very slightly from the air in the open spaces of large towns. This extraordinary uniformity in composition is brought about by several forces which are always at work purifying the air. These are:

1. *The rain*, which, as it falls, washes the air free from most of the suspended impurities. It also removes the greater part of the organic impurities as well as any acid gases; *e.g.* oxides of sulphur, oxides of nitrogen, etc.
2. *The winds*, which dilute and sweep away impurities, and bring a supply of pure air to take their place. Diffusion also assists in the dilution of impurities.
3. *The green parts of plants*, which, when the sun is shining upon them, possess the power of absorbing carbon dioxide from the air, keeping the carbon as their food, and setting free the oxygen.
4. *The oxygen* in the air—especially when in the form of ozone—which gradually oxidises and renders harmless the organic matters.

Ozone may be detected in the open air of seaside and country places. It is oxygen in an extremely active condition, and is able to attack and render harmless any waste organic matter. When it does this it is converted

into ordinary oxygen and so it is never found in towns, because there are always large quantities of organic waste in these places.

The impurities in the air are divided into:

A. Suspended impurities
B. Gaseous impurities.

Suspended Impurities.

The presence of these impurities is shown when a ray of sunshine enters a darkened room. The particles thus made visible are only the larger and coarser ones, by far the greater number being invisible to the naked eye. They are of the most varied nature, and some are injurious, while others are comparatively harmless. They are best classified into (*a*) inorganic particles and (*b*) organic particles.

The **inorganic particles** include fine particles of sand, coal, carbon, soot, common salt, clay, and many of the suspended impurities that are produced in several trades and manufacturing processes. These inorganic suspended impurities are, as a rule, comparatively harmless unless in excess. When in excess, however, they act as mechanical irritants to the eyes and lungs, and tend to produce bronchitis, emphysema, and fibroid phthisis. The character of the particles, rather than the source of the dust, determines the amount of the injury that they will produce if inhaled. The sharp, hard, and angular particles are the most injurious. These become impacted in the walls of the air-cells and bronchioles, and, not being dislodged by expectoration, set up a chronic inflammation of the tissues of the lungs. A smaller class of inorganic suspended particles are injurious because they are capable of acting as poisons, *e.g.* white lead and phosphorus.

The **chief trades** in which the workers are exposed to the inhalation of inorganic dust may be classified according to the kind of particles they evolve.

1. *Metallic irritating particles.* This kind of dust is given off in the dry grinding of cutlery, tools, files, needles, and general metal work. Th

in these trades suffer largely from phthisis, bronchitis, and pneumonia.

2. *Mineral irritating particles.* The chief sufferer from this kind of dust appears to be the Cornish tin miner. The particles of stone dust which he inhales are sharp and angular, and moreover he works in a heated and vitiated atmosphere. The mortality among coal miners from this cause is not half so great, because the particles are not so sharp and angular. In this class must also be included the dust from stone working and grindstone making; also earthenware, china, and pottery manufacturing, the workers in which suffer enormously from bronchitis and emphysema. In the best factories, however, this dust is collected and removed by mechanical brushes and fans.
3. *Poisonous particles.* Printers, earthenware manufacturers, plumbers, painters, and file makers are all subject to *lead poisoning.* This is due to some extent to the inhalation of oxide of lead, but more usually to the mixing of lead or its compounds with the food when meals are eaten with imperfectly cleaned hands. The usual symptoms of lead poisoning are (1) obstinate constipation and colic; (2) lead palsy, often called wrist drop; (3) the blue line on the gums. Workers in copper and brass foundries are subject to a special form of ague, and to obscure nervous disorders. These are probably due to the inhalation of poisonous fumes and not actual suspended particles. In match making—where yellow or ordinary phosphorus is used—a disease of the jaw bones is prevalent. Arsenical poisoning occurs among the makers of artificial flowers and arsenical wall papers. Here also the injurious effects are more probably produced by the inhalation of poisonous vapours than by actual particles.

The general methods of removing or reducing the

dangers from the above trades may be thus summarised:—

(*a*) Increased cubic space should be provided for the workers, and more efficient ventilation established.

(*b*) Screens and fans may be arranged so that the dust is carried away from the operator and out of the room as quickly as possible.

(*c*) No meals should be allowed in workshops.

(*d*) Lavatories should be provided, and the workers encouraged to pay great attention to the cleanliness of the hands and nails.

(*e*) Harmless materials should be substituted in every possible case, *e.g.* the glaze used in the potteries can now be made without any lead; red or amorphous phosphorus may be substituted for yellow phosphorus.

The **organic suspended particles** vary even more greatly than the inorganic. The more common include starch cells, pollen grains, and minute seeds of plants; fine fragments of wood, wool, cotton, silk, and hair; also particles of fat, scales of skin, bacteria, and their spores. Although the majority of these particles are quite harmless, yet it is undoubtedly a fact that they form a powerful factor in the spread of disease. Thus the dried particles of expectoration from consumptive persons may convey the disease to others, especially to those who live with them in a badly ventilated room. In a similar way the dried scales of skin from cases of small-pox and scarlet fever may carry the germs of these diseases to a considerable distance.

Organic dust is also given off by several manufacturing processes. For instance, in artificial manure works a large amount of animal dust is produced, which may be more or less of a septic nature; in factories for working hemp, jute, flax, cotton, wool, and silk the dust from these materials is extremely irritating and often produces serious ill-health. Carpenters, joiners, and cabinet makers are exposed to wood dust.

Gaseous Impurities.

These impurities are poured into the air by (1) the respiration of men and animals; (2) combustion; (3) fermentation and putrefaction; (4) some trade processes. The special impurities produced by respiration are treated in the following chapter.

Impurities from combustion. These are chiefly carbon dioxide, CO_2, sometimes called carbonic acid gas; water vapour, H_2O; sulphur dioxide, SO_2; and occasionally carbon monoxide, CO, sometimes also called carbonic oxide. *Coal*, when burned, usually produces carbon dioxide, sulphur dioxide, and water vapour, but if burned with an insufficient supply of air a considerable quantity of carbon monoxide is produced. *Coke* and *charcoal* are especially liable to form this gas when the combustion takes place in closed stoves. Carbon dioxide (carbonic acid gas) when present in the air even to the extent of 2 per cent. appears to have no injurious action on health, provided that it is not accompanied by other impurities. Carbon monoxide (carbonic oxide), on the other hand, is very poisonous. Deaths have occurred from the inhalation of air containing as little as 0·4 per cent. This gas has no smell or colour and so it is not perceived by the victim, who quickly loses the power of movement and seems to have no desire to make any effort to escape. The chief cause of its excessively poisonous properties is its affinity for the haemoglobin of the red corpuscles, with which it quickly combines and forms a peculiar cherry-coloured compound, so that the red corpuscles can no longer act as carriers of oxygen to the tissues, and death from asphyxia soon follows.

A molecule of carbon dioxide consists of an atom of carbon combined with two atoms of oxygen, as shown by the formula, CO_2, while a molecule of carbon monoxide consists of one atom of carbon and one atom of oxygen.

Coal gas, when burned, yields ½ cubic foot of CO_2 and a small quantity of SO_2 for each cubic foot of gas consumed. Other illuminants, such as candles or paraffin, yield a greater amount of CO_2 if the same amount of light is required, but as a more localised illumination is usually

tolerated from lamps and candles the actual vitiation of the air is less when these are used than when gas is employed. A serious objection to the use of gas as an illuminant is the presence of a small quantity of sulphur dioxide in the products of its combustion. This gas, though probably not present in sufficient quantities to injure health, will act injuriously on pictures, the binding of books, and on vegetable life.

Coal gas may find its way into a house from defective pipes and burners, or from leaky or cracked mains in the street, having first of all mixed with the ground air and thus entered the basement of the house. The results of continually breathing small quantities of this gas appear to be various throat affections and general deterioration of health. In larger quantities, the effect would soon be fatal, owing to the presence of carbon monoxide in coal gas.

Impurities from fermentation and putrefaction. A considerable proportion of the carbon dioxide in the air is produced by the various processes of fermentation and putrefaction that are constantly going on. Thus the air in marshy districts may contain as much as ·8 of CO_2 per 1000 volumes. Unfortunately, when the fermentation and putrefaction takes place in cesspools and badly constructed sewers and drains, the carbon dioxide is accompanied by sulphuretted hydrogen, carbon bisulphide, and some complicated organic vapours, all of which are extremely injurious to health if they obtain entrance to a dwelling. It is also very probable that poisonous alkaloidal substances called ptomaines and leucomaines may accompany the vapours which are given off by the decomposition of animal matter. Provided that these gases are poured into the open air only, it is very unlikely that they are capable of producing any injury to human beings, but if they gain access to the house they give rise to what is known as mephitic poisoning. The symptoms of acute mephitic poisoning, which is very rare, are vomiting, purging, headache, prostration, and convulsions. Chronic cases are much more frequent, and are marked by general ill-health, gastric and intestinal derangement, tendency to

boils and sore throat, and slight cough. In large towns, possessing only a very indifferently planned sewerage system, wholesale conversions into water-closets, and still more so, the provision of indoor water-closets, has not met with the success expected by ignorant sanitary enthusiasts. The reason is probably that a more perfect connection has been established between the dwelling houses and a foul, stagnant, and putrefying sewer. The result is that cases of enteric fever, diphtheria, erysipelas, etc., occur where the sanitary authorities are least expecting them, and the general public is led to look with suspicion upon the ideas of modern sanitation. No system of "disconnection," however perfect it may appear to be, can be relied upon to protect a house from the gases in a foul sewer. The universal adoption of the water carriage system in dealing with excreta will never produce the anticipated results until municipal authorities realise that the inhabitants of any house connected with an old-fashioned, badly laid sewer are constantly exposed to the danger of infection.

One of the chief causes of the summer diarrhoea which is so common in the badly drained districts of large towns is the contamination of the air by the products of the decomposition of sewage, which either putrifies in the foul sewers, or escapes through the defective sewer walls into the surrounding soil. When the necessary temperature has been reached various bacterial forms of life are able to flourish in this polluted soil, and these probably play an important part in the production of this disease.

The ground air of crowded graveyards and vaults contains excess of carbon dioxide and some organic impurities. This will produce no injurious results if it escapes into the open air, but if it finds its way into a dwelling would probably give rise to similar symptoms to those of chronic mephitic poisoning.

The air over marshes usually contains excess of carbon dioxide as well as sulphuretted hydrogen, marsh gas, and organic gases. The suspended matter in such air consists of fungi, bacteria, and general vegetable débris.

Gaseous impurities from trades. Injurious gases are evolved in alkali, chemical, and vitriol works; also in the manufacture of bleaching powder and chemical manure. Miners are exposed to carbon dioxide, marsh gas, and the products of the explosion of blasting powders. Arsenical vapours are often present in works where ores are roasted, and zinc fumes are given off in the process of brass-founding. The use of carbon bisulphide in indiarubber works leads to the presence of this vapour in the air if special precautions are not taken. In addition to the above trades there are other processes evolving offensive gases which, however, are not necessarily injurious, *e.g.* bone-boiling, glue-making, brick-making, etc.

MOISTURE IN AIR.

Evaporation is constantly going on from the surface of water and from moist earth, but the rate is continually varying. At the same time large quantities of water vapour are being poured into the air by the respiration of animals and many cases of combustion.

If the temperature were kept fixed, a limit would soon be reached and the air would then be incapable of receiving any more water vapour, and no more evaporation would go on from the surface of water. When the air at any given temperature contains as much water vapour as it can hold it is said to be *saturated*, and while it is capable of holding more it is *unsaturated*. The warmer the air the greater is the amount of water vapour that it can hold. If, therefore, the temperature of a certain quantity of saturated air be raised it ceases to be saturated and becomes unsaturated, because it is now capable of taking up more water vapour. On the other hand, if the temperature of a given volume of saturated air is lowered it becomes incapable of holding so much water, therefore some of it appears in the form of rain or dew. If some unsaturated air is cooled sufficiently a temperature is eventually reached at which the amount of moisture is sufficient to make the air saturated. This temperature is

called the "**dew point.**" If the air is now still further cooled a deposit of dew takes place. This is easily illustrated by placing a flask filled with cold water in a hot room. It soon becomes covered with a deposit of dew.

When air is close to its saturation point it is said to be moist, and when far from saturated it is called dry air. As a rule the atmosphere contains from 1 to 1½ per cent. of water vapour. The amount of water vapour present in the air is not usually expressed as a percentage, *i.e.* the number of grains of water contained in 100 grains of air. It is more usually expressed in terms of the "**relative humidity,**" which gives far more useful information than the simple percentage does. Relative humidity may be defined as:—

The amount of—

$$\frac{\text{water vapour actually present in a given volume of air}}{\text{water vapour that would be present if the air were saturated}} \times 100.$$

This is best illustrated by actual figures. The following table shows roughly the number of grains of water that will saturate a cubic foot of air at the given temperatures:

2	grains	at 30° F.	8½	grains	at 72° F.
3	,,	,, 41° F.	9	,,	,, 74° F.
3½	,,	,, 45° F.	9½	,,	,, 75·5° F.
4	,,	,, 49° F.	10	,,	,, 77° F.
4½	,,	,, 53° F.	10½	,,	,, 78·5° F.
5	,,	,, 56° F.	11	,,	,, 80° F.
5½	,,	,, 59° F.	11½	,,	,, 81·5° F.
6	,,	,, 61° F.	12	,,	,, 83° F.
6½	,,	,, 64° F.	12½	,,	,, 84·5° F.
7	,,	,, 66° F.	13	,,	,, 86° F.
7½	,,	,, 68° F.	13½	,,	,, 87° F.
8	,,	,, 70° F.	14	,,	,, 88° F.

Thus if air at 49° F. contained 4 grains of water per cubic foot it would be saturated, or its relative humidity would be

$$\tfrac{4}{4} \times 100 = 100 \text{ degrees of humidity.}$$

Again, if air at 70°F. contained 4 grains of water per

cubic foot it has only four grains out of a possible eight, and the relative humidity would be

$$\frac{4}{8} \times 100 = 50 \text{ degrees.}$$

If this air cooled down to 49°F. it would become saturated, because the 4 grains of water are all it can hold now, so that 49° would be the dew point.

The sensations of moisture and dryness of the air depend entirely upon the relative humidity and not upon the actual quantity of water vapour that may be present; so that there may be a far greater quantity of water in the air on a hot dry summer's day than on a cold damp winter's day. With moderate temperatures the most agreeable degree of humidity is between 65 and 75 degrees. Excessive humidity of the air is undoubtedly depressing and enervating. A hot moist atmosphere is particularly unpleasant, while very high temperatures may be borne without discomfort if the air is dry. A low degree of humidity appears to suit persons suffering from the early stages of phthisis, and their removal to such a climate is often attended by most satisfactory results.

As a general rule the less the relative humidity of the air the brighter and more exhilarating it feels. A cubic foot of dry air at 60° F. and the ordinary atmospheric pressure weighs 536·27 grains, while a cubic foot of saturated air at the same temperature and pressure weighs 532·74 grains, *i.e.* the saturated air weighs less than an equal volume of dry air. Now the height of the barometer depends upon the weight of the air above it; it therefore follows that the greater the percentage of water vapour in the air the lower will the barometer read.

The instruments by means of which the amount of moisture in the air can be determined are called hygrometers. They are divided into two kinds, indicating the dew point directly or indirectly. Daniel's hygrometer may be taken as an example of those instruments by which the dew point is determined directly, and the "wet and dry bulb thermometer" is one that gives the dew point indirectly. Both these instruments are described at the end of the chapter, in the part devoted to practical work.

RAIN AND RAINFALL.

Cause of rain. Rain is produced by the cooling of air below its dew point. When warm air is in contact with the surface of water evaporation takes place very rapidly, and the density of the air becomes less. The warm moist air then rises, and in the higher regions it becomes suddenly cooled either by contact with the cold mountain-tops or by meeting currents of cold air. Being cooled below its dew point it is no longer capable of holding its moisture which is then deposited in the form of rain. This may be illustrated by the warm moist westerly winds which reach the western coast of the British Isles, and, being cooled there, deposit large quantities of rain, thereby causing the rainfall to be more than double that on the eastern coast.

Rainfall. It is usual to measure rainfall in **inches.** By an inch of rain is meant an amount which, if none were lost by evaporation, percolation, etc., the ground would be covered with water one inch deep. The average annual rainfall in Great Britain is about 35 inches, varying from about 20 inches on the east coast to about 70 inches on the west coast of Ireland and Scotland. In certain parts of Cumberland it amounts to 150 inches. In one day it rarely exceeds one inch in the country, though on certain occasions as much as 5 inches have been registered.

The rainfall of a district is influenced by many conditions. Among these may be mentioned:—

1. *Distance from the sea.* Other conditions being the same a place near the sea will probably have a greater rainfall than one farther away. Proximity to the sea produces, generally speaking, a temperate, equable, and humid climate. On the other hand a wind that has already passed over land before it reaches a place has probably deposited the greater part of its moisture on the way.

2. *The direction and nature of the prevailing wind.* For instance, if a place is exposed to a westerly wind during the greater part of the year, it is obvious that the rainfall will depend upon the nature of this wind. If it comes from

warmer climates and is laden with moisture, like the west wind in England, the rainfall will be high; if it comes from a colder climate and has passed mainly over land, like the east wind in this country, the rainfall will be low.

3. *The neighbourhood of hills and mountains.* Mountainous districts have a greater rainfall than the plains, even when at a distance from the sea. The tops of mountains are usually cold, and they lower the temperature of the warm air in the higher regions below its dew point, thereby causing a fall of rain. On the other hand if the neighbouring mountains are situated so as to receive the rain-bearing wind before it reaches the place, the rainfall will be small, as shown by the almost rainless district of the Saskatchewan, which lies to the east of the Rocky Mountains. The moist westerly winds from the Pacific meet these mountains, become chilled, and deposit a great quantity of rain on their western slopes, but pass on, cold and dry, over the eastern districts.

4. *The height of the district* above the sea level also influences the rainfall. The mean annual rainfall increases up to a certain altitude, above which it diminishes. The elevation at which the maximum rainfall takes place depends upon exposure to rain-bearing winds, the trend of the valleys, etc., and so it varies with the locality. It may be taken to average between 3000 and 4000 feet.

5. *The presence or absence of vegetation.* Forests diminish the radiation of heat from the soil, thereby making hot climates cooler and increasing the rainfall. It is a well-known fact that the trees in a forest and the air around them are cooler during the day than the air in the open. If, therefore, a current of air passes from the open into the wood it may become cooled below its dew point, and deposit dew or rain. In Palestine the destruction of forests has reduced fertile regions to deserts, whereas the recent systematic planting of trees in Egypt is already increasing the scanty rainfall of that country.

In some districts the water supply depends upon the rainfall, and in these cases it is of importance to know exactly the quantity that would be received by a given collecting surface. Suppose, for instance, the average

rainfall in a district was 30 inches, and it was necessary to know the amount of water that would be collected by a flat roof measuring 60 feet by 40 feet.

Total volume of water collected $= 60 \times 40 \times \frac{30}{12}$ cu. ft.
$= 6000$ cu. ft.

Taking $6\frac{1}{4}$ gallons to the cu. ft. $= 6000 \times 6\frac{1}{4}$ galls.,
$= 37500$ galls.

In practice it is usual to allow one-fifth of the total rainfall for loss by evaporation.

$\therefore$ loss by evaporation $= \frac{37500}{5} = 7500$ galls.

$\therefore$ amount collected $= 37500 - 7500$
$= 30000$ galls.

Measurement of Rainfall—the Rain Gauge. The rainfall is measured by an instrument called the rain gauge. This

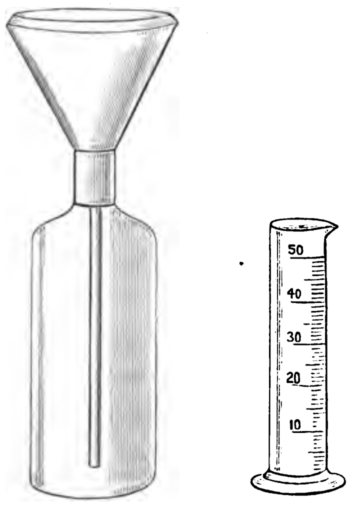


Fig. 1.—Rain Gauge and Measuring Glass.

in its simplest form, consists of three parts—(*a*) a glass or copper funnel to collect the rain. (*b*) A glass or metal vessel

to receive the water collected by the funnel. (The stem of the funnel is made narrow and passes to the bottom of the receiving vessel.) (*c*) A measuring glass, graduated according to the area of the mouth of the funnel, so as to indicate the fall of rain in decimals of an inch. For instance, suppose the diameter of the funnel is 8 inches, *i.e.* its radius is 4 inches.

$$\begin{aligned} \text{Now area of a circle} &= \tfrac{22}{7} \times (\text{radius})^2 \\ \therefore \text{ area of mouth of collecting funnel} &= \tfrac{22}{7} \times 4^2 \text{ sq. in.} \\ &= \tfrac{22}{7} \times 16 \text{ sq. in.} \\ &= 50\tfrac{2}{7} \text{ sq. in.} \end{aligned}$$

Therefore if one inch of rain fell in the funnel the receiver would contain $50\frac{2}{7}$ cubic inches of water. For convenience in measuring, this volume should be expressed in fluid ounces or in cubic centimetres.

$$\begin{aligned} 1 \text{ cu. in.} &= \cdot 59 \text{ fluid oz.} \\ \text{or } 1 \text{ cu. in.} &= 16\cdot 4 \text{ cu. cm.} \\ \text{Using these factors, } 50\tfrac{2}{7} \text{ cu. in.} &= 29\tfrac{1}{3} \text{ fluid oz.} \\ \text{or } &= 824\cdot 3 \text{ cu. cm.} \end{aligned}$$

The next step is to measure this quantity of water, *i.e.* $29\frac{1}{3}$ fluid ounces, or 824·3 cubic centimetres, and pour it into the measuring glass. If the vessel is now marked with a line at the level of the water that line will represent the graduation of an inch of rain. By dividing the glass below this mark into 100 equal parts we shall have graduations corresponding to $\frac{1}{100}$ of an inch, or ·01 inch. Sometimes a smaller measuring glass is used. In this case it is usual to calculate the volume of water corresponding to half-an-inch rainfall, and to graduate the glass in the same way; in this case there should, of course, be only fifty subdivisions if each is to count $\frac{1}{100}$ of an inch.

The **position** of the rain gauge is important. It should be placed in an exposed position so that the top of the funnel is a foot from the ground. The spot should be clear of shrubs, trees, buildings, and all objects whose height is greater than their distance from the gauge. A rain gauge should never be placed upon a house roof unless no other open position can be obtained, as it is found in practice that a smaller amount of rain is registered in these positions owing to the up-current

of air produced by the wind impinging against the surface of walls.

The gauge should be visited every day, usually at 9 a.m. The funnel should be carefully removed, the water poured into the graduated measure, and the reading noted. In winter the upper edge of the funnel is fitted accurately with a vertical rim about 6 inches in depth in order to retain snow which would be very liable to be blown out of the funnel. When snow is collected it should be melted by adding a measured quantity of warm water to it: then the total amount is measured and the volume of the warm water subtracted from it in order to ascertain the amount of water collected in the form of snow.

PRACTICAL WORK ON CHAPTER I.

THE EXAMINATION OF AIR.

For all practical purposes the determination of CO_2, and the examination of the suspended matters in air are all that is generally required. The value of the CO_2 determination is that, if it has been produced by respiration, it serves as an index of the organic matter that must have been poured into the air with it. It is extremely unlikely that the CO_2 is present in sufficient quantities to be harmful, because that gas, when produced by other processes than respiration, is so inert that there may be as much as 1·5 or 2 per cent. of it in the air without producing injurious results. Carbon dioxide from the lungs is, however, always accompanied by very poisonous organic impurities which are much more difficult to estimate than the CO_2. It is, therefore, much more convenient to estimate the amount of CO_2 present and to infer from this whether the organic impurity, which accompanies it, is likely to be harmful or not.

1. To detect the CO_2 in air.

Pour about 50 c.c. limewater into a Winchester quart bottle. Put in the stopper and shake well. The limewater is turned milky, showing the presence of CO_2.

2. **To estimate the amount of CO_2 in the air.**

Required—(*a*) A standard solution of oxalic acid containing 2·84 grammes per litre. In its neutralising power this solution is of such a strength that 1 c.c. of it is equivalent to ·5 c.c. of CO_2 at 0°C. and 760 mm. pressure. (*b*) A small quantity of solution of phenolphthalein as an indicator. This substance produces a beautiful purple colour in an alkaline liquid, but becomes colourless when sufficient acid is added to the liquid to make it neutral. (*c*) Some filtered limewater. (*d*) A large clean stoppered bottle with a capacity of about 3 litres. (*e*) Two burettes. Measure 50 c.c. of the limewater into a beaker, add a few drops of phenolphthalein, and then run in the oxalic acid solution from a burette until the last drop causes the pink colour to disappear. Note the volume of oxalic acid solution required to do this.

Blow air from a pair of bellows through the large bottle so that you may be sure you are analysing the air from the room. Then measure 50 c.c. limewater into the bottle, put in the stopper, and shake the contents vigorously. Now allow the limewater to remain in contact with the air for about three hours, shaking the bottle well from time to time. At the end of that time empty the contents into a clean beaker and wash out the bottle three times with a little distilled water which is also poured into the beaker. Add a few drops of phenolphthalein and then run in the oxalic acid solution until all the colour has disappeared. Note the number of cubic centimetres of oxalic acid solution required to do this. It will be found that a smaller amount of oxalic acid is required to neutralise 50 c.c. limewater after it has absorbed the CO_2 in the bottle than the 50 c.c. limewater in the first instance. The reason is that the CO_2 had already neutralised some of the second quantity of limewater when it was standing in the bottle and so a smaller amount of oxalic acid is required to finish the neutralisation. The difference between the two quantities of oxalic acid solution will evidently give the amount of acid equivalent to the CO_2 in the bottle. The capacity of the bottle must now be measured. Fill it with water and pour the water into a measure. Read off the volume of water and this gives the volume of air that was in the bottle. Read the temperature t° of the room with a centigrade thermometer. Then

$$\text{capacity of bottle} \times \frac{273}{273 + t}$$

gives the volume of air corrected for temperature. It is not usually necessary to correct the volume for pressure. The figures in the following experiment will illustrate the method of calculation.

(*a*) 50 c.c. limewater were taken and titrated with standard oxalic acid solution. This required 43·5 c.c. oxalic acid solution to neutralise it.

(*b*) Another 50 c.c. limewater were run into a Winchester quart bottle and allowed to stand for five hours, the bottle being well shaken from time to time.

(*c*) The contents of the bottle were emptied into a beaker and the rinsings of the bottle added. On titration with oxalic acid solution this required 39·8 c.c.

∴ The CO_2 in the bottle neutralised the same amount of lime water as would be neutralised by 43·5 – 39·8 c.c., that is by 3·7 c.c. oxalic acid solution.

But the oxalic acid solution is made so that 1 c.c. is equivalent to ·5 c.c. of CO_2.

∴ 3·7 c.c. are equivalent to 3·7 × ·5 c.c. of CO_2, *i.e.* 1·85 c.c. of CO_2.

(*d*) The bottle was found to hold 3215 c.c. The temperature of the laboratory was 19°C.

∴ corrected volume $= 3215 \times \frac{273}{292}$.

$= 3004$ c.c.

∴ 3004 c.c.air contained 1·85 c.c. of CO_2.

∴ 100 c.c. air contained ·061 c.c. of CO_2.

∴ the air of the laboratory contained ·06 per cent of CO_2.

3. **To estimate the amount of organic matter in air.**

This, as previously explained, is not usually determined, but is inferred from the amount of CO_2 that is present. For a qualitative or comparative test it is sometimes determined how much air it takes to decolourise 1 milligramme of potassium permanganate in dilute acidified solution. The necessary amount of acidified permanganate is shaken up with different volumes of air until such a volume is taken as contains exactly the amount of organic impurity to just decolourise it. Obviously, the more impure the sample of air is the less will be the volume of it that is required to decolourise the permanganate.

4. **Test for ozone.**

Dissolve a crystal of potassium iodide in a few drops of water and add to the solution a small quantity of solution of starch. Soak in this mixture several strips of white blotting paper. If these strips are exposed to air containing ozone they will turn blue. Ozone cannot be detected in the air of a room under ordinary circumstances, and so the test should be applied to some prepared ozone. Pour some oil of vitriol into a shallow dish and sprinkle into it a small quantity of barium peroxide. A gas is given off, which is oxygen containing some ozone. Hold one of the strips in the gas; it is turned blue by the ozone. This test is not absolutely reliable because there are other gases which will produce the blue colour. Ozone is distinguished from these gases by its property of turning blue a piece of red litmus paper soaked in potassium iodide.

5. **The relative proportions of oxygen and nitrogen in air** are roughly estimated as follows:—Take a glass tube about 1 inch wide and 18 inches long, closed at one end, and provided with a well-fitting cork for the open end. Put into the tube a piece of phosphorus about

as large as a pea, press in the cork, and gently warm the tube near the phosphorus. (Great care should be taken when using phosphorous, and it must always be cut under water.) The phosphorus takes fire and melts. Turn the tube so as to cause the melted phosphorus to run along the sides. The phosphorus, in burning, combines with and removes all the oxygen from the air. When all signs of burning are over, hold the corked end under water and remove the cork. Then fix the tube so that the open end is under water, and leave it until it is quite cold. You will then find that the water has risen $\frac{1}{5}$ of the way up the tube to take the place of the oxygen removed. The remaining $\frac{4}{5}$ are filled with a clear colourless gas which is nitrogen. Place an indiarubber pad under the open end of the tube and carefully invert it, so that the nitrogen takes its place at the open end. Light a taper and push it down into the gas. The gas puts out the taper, showing that it will not support combustion.

6. **Suspended matters in air.**

(*a*) A rough method of investigating the nature of the suspended particles in air is to collect the dust wherever it is deposited and examine it microscopically.

(*b*) Fit up two 8 oz. wash bottles as in fig. 2, connect them with an aspirator so that the air is drawn in the direction shown by the arrows. Put 100 c.c. distilled water into each bottle and draw the air slowly

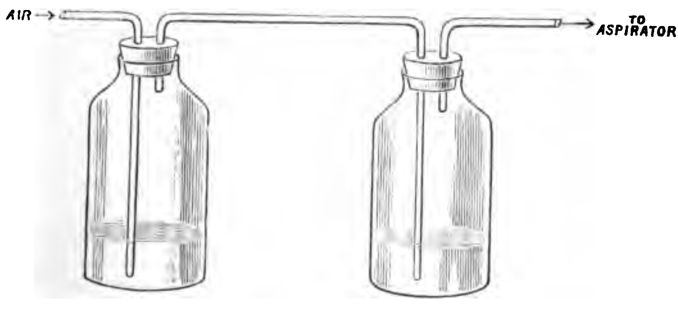


Fig. 2.

through the apparatus for about two hours. Then pour the water from both bottles into a porcelain dish and warm it gently over the bunsen flame until there is only 50 c.c. left. Remove a drop of this to a microscope slide, cover with a cover slip, and examine under the microscope.

(*c*) Another excellent method is by means of the apparatus shown in fig. 3. *A* is a microscope slide smeared with pure, clean glycerine. The tube *B*, which is drawn out to a very small diameter, ends

opposite the centre of A. The tube C is connected to the aspirator. Draw a slow current of air through the apparatus for about half an hour, then remove A and examine it under a microscope.

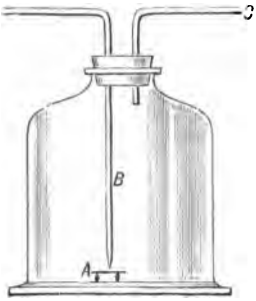


Fig. 3.

(*d*) Another plan entails the use of a soluble filter, *e.g.* of pure sugar. A glass tube about 1 inch diameter is used. One end should be drawn out to attach to the aspirator (or an indiarubber bung fitted with a narrower tube may be used) and the other end left open. The tube is then loosely packed with fine crystalline sugar for several inches, and air is drawn through the tube for about two hours. The sugar is then shaken out into as much warm water as is necessary to dissolve it readily and a drop of the liquid may be examined microscopically. If it is required to know the weight of suspended impurities in a cubic metre of air the aspirated air is measured, and the suspended matter is separated from the dissolved sugar by filtration through a weighed Swedish filter paper. The contents of the filter paper are then washed with distilled water and the paper dried in an oven at about 180°F. It is then weighed. The gain in the weight of the filter paper gives the weight of suspended impurities in the volume of aspirated air.

(*e*) The methods of examination of the suspended impurities for bacteria are of the utmost importance, but are beyond the scope of this book.

HYGROMETRY.

1. The Wet-and-Dry-Bulb Thermometer.

This is the commonest form of hygrometer. The instrument consists of two ordinary thermometers fixed side by side on a frame. The bulb of one of the thermometers is covered with muslin which is kept constantly moist by means of a piece of lamp-wick which dips into a vessel containing distilled water.

The evaporation of the water from the muslin surrounding the wet bulb causes heat to be absorbed, and so the wet-bulb thermometer usually registers a lower temperature than the dry one. The difference between the two readings depends upon, and is a measure of, the dryness of the air. If the air is dry there will be rapid evaporation taking place from the wet bulb, causing rapid absorption of heat, and so the reading of the wet-bulb thermometer will be considerably lower than the dry one. On the other hand, if the air is

moist and nearly saturated there will be little difference between the two, because evaporation takes place very slowly under these conditions. If the air is saturated there will be no evaporation and the readings will be the same.

Exp. 1. Place a thermometer in a vessel filled with water that has been in the room for an hour. Note its reading, and then take it out of the water and note the effect of the evaporation from the wet bulb.

Exp. 2. Repeat the experiment, but after taking the thermometer out of the water move it rapidly to and fro. This causes the evaporation to take place much more quickly than in Experiment 1. Note the reading and put down what you infer as to the effect of rapid evaporation.

Exp. 3. Dip the bulb of a thermometer into methylated spirit, withdraw it and allow the spirit to evaporate. Note the effect of rapid evaporation upon the temperature registered by the thermometer.

Exp. 4. Pour a few drops of water on the top of a block of wood. In this water place a small beaker. The bottom of the beaker is now connected to the top of the wood by a thin film of water. Pour a small quantity of ether into the beaker and direct a stream of air upon the surface of the ether. (N.B.—No flame should be allowed on the bench where ether is being used.) The stream of air causes rapid evaporation to take place, and this absorbs so much heat that the beaker becomes frozen to the wood.

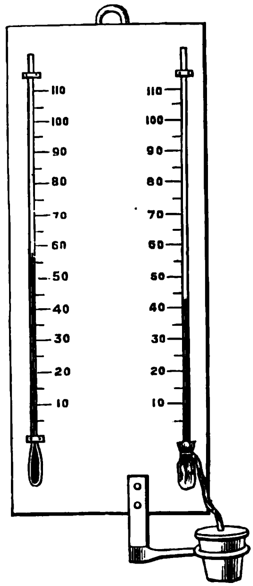


Fig. 4.—The Wet-and-Dry-Bulb Thermometer.

Exp. 5. *To use the wet-and-dry-bulb thermometer.* The instrument should be placed in the shade, 4 feet from the ground, and protected from air currents and direct sunshine. Note the readings of the two thermometers.

	Wet bulb.	Dry bulb.	Difference.
Example :	54°F.	60°F.	6°F.

The " dew point " may be roughly calculated from these figures by assuming that it is as much below the reading of the wet-bulb thermometer as this reading is below that of the dry one, *i.e.* 54° – 6° = 48°F.

In order to ascertain the dew point more exactly it is necessary to use certain factors which have been worked out by Mr. Glaisher.

Temperature of air, *i.e.* of dry bulb.	Factor.	Temperature of air, *i.e.* of dry bulb.	Factor.	Temperature of air, *i.e.* of dry bulb.	Factor.
		°			
45°	2·16	57°	1·92	69°	1·78
46°	2·14	58°	1·90	70°	1·77
47°	2·12	59°	1·89	71°	1·76
48°	2·10	60°	1·88	72°	1·75
49°	2·08	61°	1·87	73°	1·74
50°	2·06	62°	1·86	74°	1·73
51°	2·04	63°	1·85	75°	1·72
52°	2·02	64°	1·83	76°	1·71
53°	2·00	65°	1·82	77°	1·70
54°	1·98	66°	1·81	78°	1·69
55°	1·96	67°	1·80	79°	1·69
56°	1·94	68°	1·79	80°	1·68

To obtain the dew point by means of Glaisher's tables. First find the difference between the two readings—wet and dry, then multiply the difference by the factor in the above table corresponding to the reading of the dry bulb, and subtract the product from the temperature of the dry bulb.

Example (as above). Difference = 6°F.

Difference × Factor for 60°F. = 6 × 1·88.

= 11·28.

∴ Dew point = Temperature of dry bulb − 11·28.

= 60 − 11·28

= 48·72°F.

Knowing the dew point it is easy to calculate the relative humidity of the air. From page 10 we see that

Relative humidity

$$= \frac{\text{Amount of water actually present in the air}}{\text{Amount of water that would be present if the air were saturated}} \times 100$$

Now in the above example the water in the air is sufficient to saturate air at a temperature of 48·72°F. This is obvious from the definition of "dew point."

∴ Relative humidity

$$= \frac{\text{Amount of water required to saturate 1 cu. ft. of air at 48·75°F.}}{\text{Amount of air required to saturate 1 cu. ft. of air at 60°F.}} \times 100$$

amounts from the table on p. 10, it is found that water saturate 1 cubic foot of air at 48·75°F., and ains will saturate 1 cubic foot of air at 60°F.

$$\therefore \text{Relative humidity} = \frac{3·9}{5·75} \times 100$$
$$= 67·8.$$

2. Daniel's Hygrometer.

This instrument (fig. 5) consists of a bent tube with a bulb at each end. The lower bulb is partly filled with ether, and the remainder of

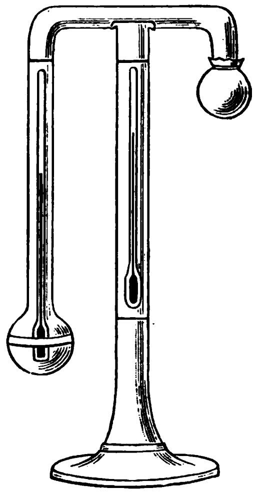


Fig. 5.—Daniel's Hygrometer.

the instrument contains only ether vapour, all the air having been expelled. The lower bulb is fitted with a thermometer, and is either blackened or surrounded by a bright metal ring, so that any condensation of moisture may be easily perceived.

Exp. 6. *To use Daniel's Hygrometer.* See that all the ether is in the lower bulb. Cover the upper bulb with muslin, and moisten it with ether. The ether on the muslin evaporates into the air and cools the upper bulb so much that the ether vapour inside it is condensed. The ether in the lower bulb then evaporates in order to

supply more ether vapour in place of that which has condensed in the upper bulb. This in its turn is condensed, and then more evaporation takes place from the lower bulb, and so on. This evaporation causes the temperature of the lower bulb to become gradually lower and lower, and finally a point is reached at which the air round the bulb begins to deposit dew on the bright surface. The moment this occurs take the reading of the thermometer in the lower bulb. This evidently should be the dew point. To ascertain the dew point a little more exactly, allow the instrument to stand after the muslin has dried. Watch the lower bulb carefully until the dew just disappears from its surface; then note the temperature again. Repeat the whole experiment, and thus obtain two more readings of the thermometer. The mean of the four readings should give the dew point accurately. From the dew point calculate the relative humidity of the air.

3. Dines' Hygrometer.

This is one of the best of the modern hygrometers. Fig. 6 illustrates the parts of this instrument. The theory of this hygrometer is exactly the same as with Daniel's hygrometer. A piece of thin blackened glass, *G*, is cooled by a stream of cold water which passes

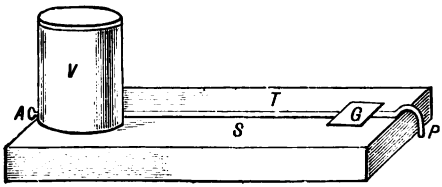


Fig. 6.—DINES' HYGROMETER.

under it. The temperature of the plate is registered by a thermometer, *T*, the bulb of which is placed just under it. The thermometer is read through the glass covering of the groove, *S*.

Exp. 7. *To use Dines' Hygrometer.* Fill the vessel, *V*, with cold water, turn on the tap, *A*, and allow the water to flow under the glass plate and out at the overflow pipe, *P*, until there is the first trace of a deposit of dew on the glass plate. Then close the tap and note the reading of the thermometer. Now wait until the dew just disappears from the plate and read the thermometer again. Take the mean of the two temperatures and this will be the dew point. Calculate the relative humidity of the air.

THE RAIN GAUGE.

uct a rain gauge. Choose a glass funnel about
Measure accurately its diameter and calculate
ıth of the funnel. This should be placed in the
jar or bottle from 12 to 15 inches in height.

aduate the measuring-glass. A glass gas-jar about
ter answers very well for this. Paste a strip of white
ə side of the glass so that the graduations may be

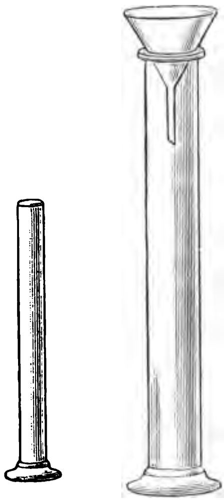


Fig. 7.—LABORATORY RAIN GAUGE.

marked. You have already calculated the area of the funnel, and so you know the volume of water that would collect in the bottle if an inch of rain fell (refer to the calculations on page 15). Measure carefully half this quantity and pour it into the gas-jar. Make a mark on the paper opposite the level of the water. This mark corresponds to half an inch of rainfall. Then divide the paper from this mark to the bottom of the jar into 50 equal parts, so that each division will correspond to $\frac{1}{100}$ of an inch.

CHAPTER II.

RESPIRATION AND VENTILATION.

Respiration.

THE respiratory apparatus consists of the lungs and of the air-passages which lead to them. The gills of aquatic animals fulfil the same functions as the lungs of air-breathing animals. There is a thin membrane in both a lung and a gill, one surface of which is exposed to air or water, as the case may be, while on the other surface is a network of blood-vessels,—the only separation between the blood and the aerating medium being the thin wall of the blood-vessels, and the delicate membrane mentioned above.

The lungs or gills are the only medium whereby the blood can *exchange* carbon dioxide for oxygen. They are not, in any special degree, the seat of those metabolic processes whereby heat is produced, for these occur in the substance of the tissues in all parts of the body.

The air on its way to the lungs passes through (*a*) the mouth or nose, (*b*) the pharynx, (*c*) the larynx, (*d*) the trachea, (*e*) the bronchi and their branches.

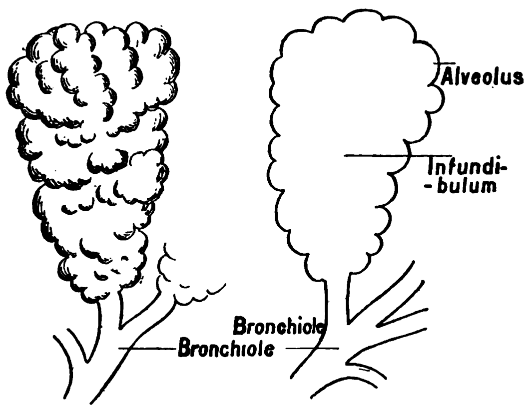
The *trachea* or wind-pipe divides into two tubes called the bronchi—the right bronchus going to the right lung, and the left bronchus going to the left lung.

The *bronchi* divide and subdivide in the substance of the lungs into a number of smaller and smaller branches called *bronchial tubes*. These penetrate into every part of the lungs and end in dilated cavities or infundibuli. Each

of these has a number of pouch-like air-cells or *alveoli* opening into it. (See fig. 8.)

The trachea is kept open by a number of C-shaped cartilage rings, having the opening behind. The branches have a similar structure to that of the trachea, but the bands of cartilage become less and less complete as the branches get smaller. Finally they are represented by scattered pieces of cartilage and entirely disappear in the smallest air-tubes.

The air-cells are about $\frac{1}{70}$ of an inch in diameter, and they have a close network of capillary blood-vessels sup-



A, Outside View. B, Section.
Fig. 8.—Termination of Bronchiole.

ported in the delicate framework of connective tissue which holds them together.

The pulmonary artery brings blood to the lungs from the right side of the heart. This blood, having circulated in the capillaries of the body, and there absorbed CO_2 with other waste material, has become deficient in oxygen, and requires re-oxygenating and purifying.

The pulmonary artery divides into two branches, one going to each lung.

These branches enter near the bronchi and subdivide in the same manner that the bronchial tubes divide as mentioned above. The smallest arteries give rise to the capillaries, which reunite, to form the pulmonary veins. The pulmonary veins carry the purified blood to the left side of the heart.

The air in the air-cells is in close proximity to the blood in the capillaries, and an interchange of gases is effected. CO_2 passes from the blood into the air, and oxygen passes from the air to the blood.

The atmospheric air does not, to any great extent, penetrate beyond the bronchial tubes. The gases which get into the smaller air-tubes do so principally by diffusion. The most vigorous expiratory effort is inadequate to expel the alveolar air. In the air-cells the CO_2 is present in larger, and the oxygen in smaller, proportions than in atmospheric air. In the intervening air-passages there is an intermediate condition. The oxygen diffuses downwards to the air-cells, and CO_2 diffuses upwards. Movements due to diffusion are slow. They are, however, assisted here by the large draughts which are produced in the upper respiratory tract by the respiratory movements of the chest.

Composition of Inspired and Expired Air.

	Inspired Air.	Expired Air.
Oxygen.	20·96 vols. per cent.	16·03 vols. per cent.
Nitrogen (with argon, crypton, etc.).	79 ,, ,, ,,	79 ,, ,, ,,
Carbon dioxide.	0·04 ,, ,, ,,	4·4 ,, ,, ,,
Water vapour.	Variable.	Saturated.
Temperature.	Variable.	That of the body.
Organic matter.	——	Small quantities.

The above table shows that expired air.—

1. Contains more CO_2.
2. Contains more water vapour.

3. Contains less oxygen.
4. Is raised in temperature.
5. Contains organic impurities. (These are the most injurious of the impurities produced by respiration.)

It is found that, the greater the amount of respiratory CO_2 in a room, the greater the amount of organic matter, hence it is customary to take the amount of CO_2 present as an index of the amount of organic matter present, without measuring the organic matter directly. (See p. 16.)

Quantity of Air breathed.

(*a*) *Breathing* or *tidal air* is the quantity which is habitually and almost uniformly changed in each act of breathing. It is from 20 to 30 cubic inches in a healthy adult.

(*b*) *Complemental air* is the amount, over and above the tidal air, which can be drawn into the lungs in the deepest inspiration. This varies, but may be taken to be about 100 cubic inches.

(*c*) *Reserve* or *supplemental air*. A forcible and deeper expiration may enable 100 cubic inches additional air to be expelled.

(*d*) *Residual air*. Is the quantity which still remains in the lungs after the most violent expiratory effort. This depends upon the size of the chest but may be taken to be about 100 cubic inches.

The *Vital Capacity* of the chest is measured by the amount of air which can be expelled by a forcible expiration, after the deepest possible inspisation.

Vital capacity = complemental air + tidal air + supplemental air. This depends upon

(*a*) *Weight*. For weights of persons of the same height, from $11\frac{1}{2}$ stones to 14 stones, it is found to diminish 1 cubic inch per lb. increase.

(*b*) *Age*. Increase between ages 15 to 35, of 5 cubic inches per year. Decrease from 35 to 60, of $1\frac{1}{2}$ cubic inches per year.

(*c*) *Sex*. Vital capacity of man to woman of same height is about 10 : 7.

(*d*) *Height*. Taking 5 ft. 7 in. as the standard height, with 225 cubic inches as the vital capacity corresponding thereto, we have an increase of 8 cubic inches for each inch increase of height, and a decrease of the same amount for each inch below that.

Amount of CO_2 breathed out.

The number of respirations is from 14 to 18 per minute in a healthy adult. If we take 30 cubic inches of air expelled 16 times per minute we have :—

Amount of air expelled $= (30 \times 16)$ cu. in. per min.

Amount of air expelled $= \dfrac{30 \times 16 \times 60}{1728}$ cu. ft. per hr.

This contains 4 per cent of CO_2,

$\therefore$ amount of CO_2 expelled

$$= \frac{30 \times 16 \times 60}{1728} \times \frac{4}{100} \text{ cu. ft. per hr.}$$

$$= 0{\cdot}6 \text{ cu. ft. per hr.}$$

Pettenkofer ascertained by experiment that a man of 28 years of age weighing 132 lbs. evolved

1. At night during repose 0·56 cu. ft. of CO_2 per hr.
2. During the day with moderate exercise 0·78 cu. ft. per hr.
3. During the day with hard work 1·52 cu. ft. per hr.

Amount of fresh air required.

It is known that ordinary air contains 0·04 per cent. of CO_2.

Air, with *over* 0·06 per cent of CO_2 present, is sensibly impure, while *below* that percentage it is not noticeably so. Therefore 0·06 per cent. has been taken as the amount of impurity which may be permitted without danger to health. This will permit each 100 cubic feet of fresh air, which enters a room to take up 0·02 cubic feet of CO_2 (in addition to the 0·04 cubic feet already in it) without causing the air to be unhealthy.

The quantity of fresh air required to keep a room in a satisfactory condition may be calculated from the above as follows :—

Each person gives off 0·6 cu. ft. of CO_2 per hr.

This is mixed with the incoming air.

100 cu. ft. of fresh air can take up 0·02 cu. ft. of additional CO_2;

1 cu. ft. of fresh air can take up 0·0002 cu. ft. of additional CO_2;

Or to mix with 0·0002 cu. ft. of CO_2 we require 1 cu. ft. of fresh air.

Therefore to mix with 0·6 cu. ft. of CO_2 we require $\frac{0{\cdot}6}{0{\cdot}0002}$ or 3000 cu. ft. of fresh air.

Each person requires about 3,000 cubic feet of fresh air per hour, to be mixed with the air breathed out, to keep the air of a room in a satisfactory condition.

If more CO_2 be expelled from the lungs, more fresh air is required. *De Chaumont's Formula* is frequently used to calculate the amount required.

This formula is $\frac{e}{\rho} = d$.

In this $e =$ amount (in cubic feet) of CO_2 exhaled by an individual in an hour; $\rho =$ limit of permissible respiratory impurity (stated per cubic foot); $d =$ the required amount of fresh air in cubic feet per hour.

In the above calculation $e = 0{\cdot}6$, and the quantity required $=$ 3000 cu. ft. per hour. If $e = 0{\cdot}78$ cu. ft. (which is given off in moderate exercise) it is calculated that $\frac{0{\cdot}78}{0{\cdot}0002}$ or 3900 cu. ft. per hour is required.

If $e = 1{\cdot}52$ cu. ft. (which is given off during hard work), it is calculated that $\frac{1{\cdot}52}{0{\cdot}0002}$ or 7600 cu. ft. of fresh air per hour is required.

Angus Smith found that for a horse $e = 1 \cdot 13$.

Therefore a horse requires $\frac{1 \cdot 13}{0 \cdot 0002}$ or 5650 cu. ft. per hour.

Animals require fresh air in proportion to their size and weight.

Artificial lights, with the exception of the incandescent electric light, vitiate the air. (See *Impurities of the Air*, Chapter I.)

Additional fresh air is therefore required on account of these impurities being added to the air.

In mines 60 cubic feet per hour per light is allowed, but this is scarcely sufficient. An ordinary gas burner requires two-thirds as much fresh air as an adult; incandescent gas-lights (Welsbach) require half as much as an adult; and an ordinary paraffin lamp requires as much as an adult.

Variation in density of air due to elevation and difference of temperature.

The air envelops the earth, and is prevented from leaving it by the force of gravitation. The layers of air above press upon those below, so that the greatest pressure is found near the surface, while it decreases as the height is increased. The pressure of the air is measured by the height of the column of mercury, which it can support in a barometer tube, having a vacuum at the top.

At the sea level, *i.e.* the mean between the high and low water level at Liverpool, the pressure is equal to about 30 inches of mercury or 15 lbs. on each square inch. For moderate elevations this decreases at the rate of about one inch of mercury for 900 feet of ascent. This rate, however, is not to be relied upon at great elevations.

At 2,500 ft. the pressure is $\frac{7}{8}$ of that at sea-level;
at 5,000 ft. " " $\frac{5}{6}$ " " "
at 7,500 ft. " " $\frac{3}{4}$ " " "
and at 15,000 ft. " " $\frac{1}{2}$ " " "

Boyle's Law, which has been proved by experiments, is that:—*The volume of a given mass of gas varies inversely with the pressure to which it is subjected, if the temperature is constant.*

If the pressure on a given mass of gas at a constant temperature is decreased, the gas will expand; if it is halved, the volume will be doubled, and as the given mass of gas will occupy twice as much space, the density will be decreased one-half. If the pressure is increased, the volume will become less, and, as more gas will be compressed in a given space, the density will be greater.

The result of this is that the density of the air becomes less as greater elevations are reached.

The physiological effects of breathing this rarefied air are:—

1. Quickening of the pulse.
2. Quickened respirations.
3. Increased evaporation.
4. Disturbance of the equilibrium between the pressure of gases in the body and the external air; this occasionally causes bleeding at the nose, ears, and lungs, there being insufficient pressure on the surface to restrain the flow of blood.

The physiological effects produced have proved to be beneficial in certain cases.

The diseases benefitted by mountain air are:—

1. Anaemic affections of various kinds.
2. Neuralgia.
3. Gout.
4. Rheumatism.
5. Phthisis.

The effects of breathing compressed air are opposite to those of breathing rarefied air and they are particularly observed in connection with diving-bells, caissons, etc.

They are as follows:—

1. The pulse beats slower.
2. The rate of breathing is reduced.

3. The increased external pressure may cause pains in the head. The amount of inconvenience experienced is minimised, however, if the change from air at one pressure to that at another is not made too suddenly.

Variation in density due to difference of temperature.

Experiment shows that if the pressure of a gas remains constant, it expands $\frac{1}{273}$ of its volume at 0°C., for each increase of 1°C. in temperature; or $\frac{1}{491}$ of its volume at 32°F. for each increase of 1°F.

If the pressure is constant, the density of the gas is decreased, when the temperature is increased.

Winds are movements of masses of air.

They are caused by variations in the density of air, these being due to differences in temperature and pressure.

The trade winds, monsoons, land and sea breezes are examples of winds produced by heated or lighter air ascending and the cooler or heavier air rushing in to take its place, thus restoring the equilibrium.

The *ventilation of mines* is brought about by a constant circulation of air in the following manner: A large fire is kept burning at the bottom of one of the shafts, and the air thus heated, becoming lighter, ascends through the mouth, while cooler and heavier air passes down another shaft and rushes along from various parts of the mine to take the place of the ascended air. In this way, the vitiated air is removed and fresh air is supplied.

VENTILATION.

Ventilation is the removal or dilution of impurities in the air of buildings by means of suitably arranged inlets and exits, and should be carried on without producing draughts.

A.—NATURAL VENTILATION.

This takes place under the action of natural forces.

The *chief causes* are as follows :—

1. Diffusion of gases.

2. Winds.
3. Difference in weight of masses of air at unequal temperatures.

1. *Diffusion.*

This is a property which enables gases to mix completely, even against gravity. If the gases are of different densities, diffusion proceeds at different rates, which vary inversely as the square root of the densities.

If the density of hydrogen is represented as 1 and that of oxygen as 16, then
rate of diffusion of oxygen : rate of diffusion of hydrogen

$$= \sqrt{1} : \sqrt{16}$$

or hydrogen diffuses four times as rapidly as oxygen.

Diffusion, however, is scarcely rapid enough to dilute and remove impurities from the air of living rooms.

In addition, the organic matter introduced by expired air does not diffuse among the other constituents and therefore does not leave the room.

2. *Wind* as a ventilating agent, may act in either of two ways:—

(*a*) By *perflation, i.e.* blowing through a room, when the doors and windows are open to allow a free course for the wind. If air travels straight through a room—15 feet broad—at the scarcely perceptible rate of two miles per hour, it will be renewed $\left(\frac{2 \times 1760 \times 3}{15} \text{ or } 704 \text{ times}\right)$ say nearly 700 times per hour.

This is the most rapid method of changing the air of a room, but it is not one which can be adopted with safety, when the room is occupied. Bedrooms may, however, be flushed in this way after the inmates have risen.

Schoolrooms may be treated in a similar manner during the intervals.

Ventilation by perflation, however, cannot be depended upon as the sole method, for the rate of movement of the wind is erratic.

(*b*) *By Aspiration.*

When a body of air is moving, it drives the air before it, lessens the pressure around it, and causes air in its vicinity to move towards it.

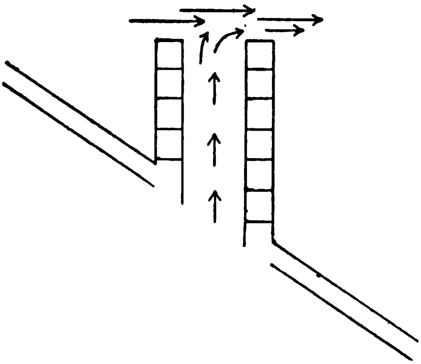


Fig. 9.—Aspirating effect of Wind passing over a Chimney.

If the wind blows over a chimney, or over any other similar air-exit, an up-draught is produced. (See fig. 9.) Air is thus extracted from a room and fresh air enters by other openings.

There are a number of appliances for ventilation which make use of this aspirating effect of the wind. Boyle's ventilators and Banner's cowls are two forms which are widely used.

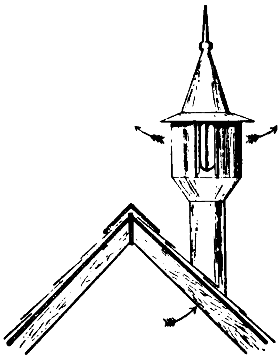


Fig. 10.—Boyle's Air-Pump Ventilator.

Boyle's *Air-pump Ventilator* has fixed openings on different sides. (See fig. 10.) The wind blowing from almost any direction, passes through some of the openings and out of the opposite ones. In doing so, air is extracted from the tube or air-exit over which the ventilator is placed.

Banner's Cowl sets itself, by means of a wind vane, so that the opening is always directed to face the wind.

(Reference has been made in a preceding paragraph to the

renewal of air of rooms by means of movements set up through differences of density between the external and internal air.)

Openings for Ventilation.

Special inlets as well as outlets must be provided. If 3000 cubic feet of fresh air has to be supplied per hour for each person, at a rate not exceeding 5 feet per second, an inlet of 24 square inches must be provided.

The amount of expansion of the air in a room depends upon the difference in temperature between the internal and external air. This expansion is usually so small, that it may be neglected and an exit similar to the inlet is required. Or for inlets, 24 square inches may be allowed, and 26 inches for exits, making 50 square inches of openings for each person.

Outlets should be provided near the ceiling, because the products of combustion and respiration, being heated, tend to rise.

Inlets should be situated somewhat lower, but care must be taken that they are not placed too near the outlets, or the air may enter and leave without improving the condition of the room.

Ventilators for rooms. The chimney is the chief ventilator; it should on no account be closed when the room is occupied. Fresh air enters by the door, windows, or the numerous cracks and crevices round them, thus replacing the air which has left by means of the chimney.

Special inlets and outlets.

These may be divided into three groups:—

1. *Window ventilators.*
   (*a*) Hinckes Bird's window-board arrangement.
   (*b*) Hinged upper section of the window.
   (*c*) Vertical holes in the middle bar of a sash window.
   (*d*) Double panes, with an air passage between them.
   (*e*) Louvre ventilators.
   (*f*) Cooper's ventilators.

2. *Openings in the lower part of the walls, with vertical shafts.*

Tobin's Tubes.

3. *Openings in the upper part of the walls, or in the ceilings or roofs.*

Inlets (*a*) Sherringham valve.
(*b*) Ellison's air-bricks.
(*c*) Jennings' air-bricks. (These are similar to Ellison's but have a small chamber into which the air is first led, and in which suspended matter is deposited.)

Outlets (*a*) Arnott's valve.
(*b*) Boyle's mica-flap ventilator.
(*c*) McKinnell's ventilator.

These various appliances are illustrated by diagrams, and are fully described, in Chapter IV. of *First Stage Hygiene* in this series.

Successful natural ventilation usually produces more *pleasant* results than artificial ventilation.

The air in a building ventilated by artificial means may not be so fresh and pleasant as in rooms where natural ventilation is successfully carried out.

B.—ARTIFICIAL VENTILATION.

The methods adopted for artificial ventilation are generally divided into two classes:—

(A) **Vacuum** or *extraction* methods, whereby the air is *drawn out* of the buildings.

(B) **Plenum** or *propulsion* methods, whereby air is *forced into* the buildings.

The chief agencies by which ventilation is artificially secured are heat, steam jets, pumps, and fans or wheels.

A. Extraction Methods.

(1) **Heat.**

The ventilation by means of the fireplace and chimney furnishes an illustration of the action of heat in changing

the air of a room. The heated air immediately over the fire expands, becomes relatively lighter than the air of the room and passes up the chimney, while fresh air takes its place and ascends in turn

This principle is utilised in the ventilation of mines as described in an earlier paragraph. (See page 34.)

The ventilation of the House of Commons is effected by means of heat. A large fire is kept burning at the foot of the Clock Tower, causing a powerful up-draught. Air enters through openings in the basement; this is filtered and washed by passing through moist screens and warmed by steam pipes; it then passes upwards by four circular shafts into the space beneath the grated floor through which it enters the House. The vitiated air ascends and leaves by the openings in the ceiling.

It enters channels or flues leading to the foot of the clock tower. The up-draught, produced by the fire, causes it to ascend the tower, whence it escapes into the open air. In summer the incoming air may be passed over ice.

Jebb's system for ventilating prisons is similar in principle, but the fires are placed near the roof. Air enters each room near the ceiling, and leaves by an opening on the opposite side, near the floor, passing into flues which conduct it to the fires.

On large steamships the extraction tubes surround the funnels of the vessel; the heat of the escaping steam and of the products of combustion is thus made use of. As the air surrounding the funnels becomes heated an up-draught is produced, which extracts the air from the parts of the vessel connected with the extraction tubes.

(2) **Steam Jets.**

At some collieries, a jet of steam is allowed to pass into a flue or chimney. This sets in motion the air in its immediate vicinity and produces an up-draught. This method is suitable for the ventilation of factories having plenty of spare steam, provided the tubes which pass from the different rooms enter the flue of the chimney below the steam jet. It was adopted in the House of Lords but was afterwards abandoned.

(3) **Pumps.**

These are used in some mines. A large vessel is moved up and down in a chamber which contains sufficient water to immerse the vessel when it descends and yet allow it to be raised entirely out of the water in ascending. The vessel, when raised out of the water, is filled with air from the chamber which communicates with the mine. In descending again, this air is expelled and passes into flues, which conduct it to the surface. Valves prevent it returning when the vessel is again raised. This method was used in connection with the St. Gothard tunnel works.

Extraction by pumps, however, is not so satisfactory as by means of a fan or wheel.

(4) **Ventilating Fans.**

A fan is a wheel with several vanes attached to the axle, and is so arranged that, as the wheel rotates rapidly, air is carried along by the vanes and caused to flow along flues or passages.

A fan may be fitted—

(*a*) To extract air from a building;
(*b*) To carry away noxious fumes arising during manufacturing processes;
(*c*) To force air into a building.

B.—Ventilation by Propulsion.

The *Blackman Air Propellor* is a fan which is widely used in the ventilation of workshops, factories, and schools. An electric fan (which is reproduced by permission of the makers) is shown in fig. 11.

The flat form of this fan enables it to be readily placed in walls or partitions. One of these fans, 4 feet in diameter, when driven at a speed of 330 revolutions per minute, is said to discharge 15,000 cubic feet of air per minute with an expenditure of 1 H.P.

In all cases where air is forced into rooms there is a great loss of energy through friction. This is enormously increased if there are right-angled bends in the air passages.

Care must be taken that the air is taken from a pure source. It may be filtered, and then warmed by passing over steam pipes, or it may be cooled by a water spray as required, before being forced into the rooms. (This combines heating and ventilation.)

A gas-engine is a very suitable appliance for driving a fan; or, if electric power is available, this may be utilised.

The ventilation of St. George's Hall, Liverpool, furnishes an example of ventilation by propulsion on a large scale.

Here there are four large fans in the basement, driven by a 10 H.P. engine. The building is heated by passing

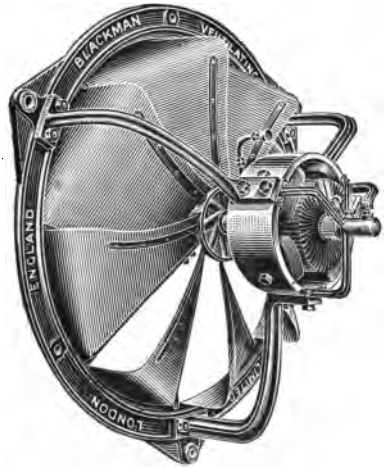


Fig. 11.—BLACKMAN'S ELECTRIC FAN.

the air through chambers containing coils of hot-water and steam pipes. After the air is warmed it is moistened by injecting steam, and provision is made for washing it by a water spray before it reaches the fans.

In the chapter on heating reference is made to a "*Report on the cost and efficiency of the Heating and Ventilation of Schools*," prepared for the Dundee School Board.

The following summary is taken by permission from that report:—

MECHANICAL VENTILATION. (Page 42.)

Advantages.

(1) Much greater purity of air as regards all the constituents.
(2) Efficiency of ventilation much more independent of the weather; whereas with other systems, the ventilation is worst when most needed.
(3) The schools are warmer.
(4) More equal distribution of heat and of fresh air.
(5) Very effective in diminishing the number of micro-organisms, not only at the time the mechanical ventilation is in operation, but also for a long time after it has been stopped.
(6) Reduces draughts to a minimum.

In fact the mechanical system heats and ventilates far better in every respect than any other system, and is therefore far more conducive to health and comfort and to success in teaching and learning.

Disadvantages.

(1) Greater first cost.
(2) Greater annual cost (except in the case of very large schools).
(3) Though in towns where several schools were heated and ventilated mechanically, there would not need to be more than one ordinary caretaker in each of such schools, yet *one* of these should be a man who had some knowledge of gas-engines, etc., so that he could attend to any repairs which might be necessary. Such a man would require a somewhat higher wage than an ordinary caretaker. This, however, would amount to very little if distributed over a number of schools.

Efficiency. (*Page* 47.)

(*a*) *Gas-engines* v. *Water-engines.* Gas-engines are much cheaper and more effective than water-engines for driving the fans.
(*b*) *Power of gas-engine required.* A 2 H.P. gas-engine is amply sufficient for driving a 4-feet Blackman fan.
(*c*) *Blowing in* v. *Exhausting the air.* The former is preferable.
(*d*) *Inlet shafts.* One large fresh-air inlet shaft is much better than several small ones, and the entrance to the shaft should be as free as possible.
(*e*) *Air-filters.* These should be made of coarse jute cloth, to remove soot and dirt.
(*f*) *Time required to change the Air of a School by Mechanical Ventilation.* By mechanical ventilation the whole of the air of a school can be changed in less than fifteen minutes, and when the system is well arranged in less than ten minutes.

PRACTICAL WORK ON CHAPTER II.

1. Fit an indiarubber bag on the end of a glass tube, pass the tube through the stopper of a bell-jar. Place the bell-jar on the plate of an air-pump with the rubber bag in the jar and partly filled with air. When air is extracted from the jar the rubber bag becomes inflated by air pressing in down the tube.

This illustrates the inflation of the lungs when the chest is enlarged by depression of the diaphragm and by elevation of the ribs.

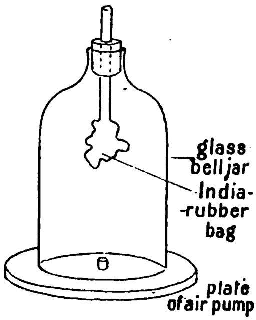


Fig. 12.—Apparatus for illustrating Mechanism of Respiration.

2. Fit the indiarubber stopper of a bell-jar with a bent glass tube, to which a short length of indiarubber tubing is attached. Place the bell-jar to stand in a large basin containing water to the depth of several inches. Place a lighted taper in the jar—it burns as in ordinary air. Take it out and replace the stopper. Inhale the air from the jar through the tube. Water will rise as air is taken out and if there is sufficient water in the basin the jar will be filled with water when the whole of the air is extracted. Breathe *the same air* back into the bell-jar, causing the water to descend On testing with a taper it will be found that this air will not support combustion.

3. To prove the presence of moisture in expired air, breathe on the surface of a cold mirror.

4. Place some limewater in two test glasses. Blow ordinary air by means of a pair of bellows through the limewater in one, and breathe expired air through the other by means of a glass tube. The large amount of CO_2 present in expired air will be very apparent by the milkiness produced. *Cf.* page 17.

5. Place a little Condy's Fluid in water. Breathe through this; the organic matter present in the expired air decolourises the Condy's Fluid.

6. Place some smouldering brown paper in a lamp chimney. Blow *across* the top with a pair of bellows, the lessening of pressure causes an up-draught which is shown by the motion of the smoke. This illustrates the action of the wind as a ventilating agent.

7. Place a lighted candle at the bottom of a cylinder (open at the top only). In a short time the candle flame is extinguished.

Take a T-piece made of metal which will fit into the top of the cylinder and divide the opening into two parts. The candle on being relighted will continue to burn.

The currents of air set up may be shown by means of smoke. Heated air passes up one side of the T-piece and fresh air down the other.

CHAPTER III.

FOOD—DIETS.

Uses of Food. These may be classified as follows :—

1. To keep up the heat of the body. The food is first digested and assimilated, it is then oxidised and reduced to simpler forms in the tissues, and is finally excreted in the form of water, carbon dioxide, urea, and some indigestible matter. As a result of the chemical combination between the oxygen and the elements of the food, heat is produced.

2. To produce the energy which results from chemical actions in which food is concerned. This energy performs the work of the body, which may be divided into two kinds, (*a*) *internal work*, which consists in keeping the different organs automatically at work, and (*b*) *external work*, such as walking, running, or other muscular exertion.

3. To repair and renew the wasted tissues, caused by the constant wear and tear of the body.

4. To form new tissue in the process of growth of young people.

Classification of Foods. All foods are composed of certain substances called *food stuffs* or *proximate principles.* Some foods contain representatives from practically all the proximate principles, while others contain one only, or mainly one, with very small quantities of one or two others. The *ultimate constituents* of foods are the chemical elements of which they are composed. These are chiefly carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus.

Foods are classified according to their source into:—(1) **inorganic foods**, which include water and the various mineral salts, and (2) **organic foods**, *i.e.* those of animal or vegetable origin. The organic foods are further subdivided

into those which contain nitrogen and those which do not. Those containing nitrogen are called **nitrogenous** or **proteid,** and those with no nitrogen are called **non-nitrogenous** foods. Non-nitrogenous foods are further subdivided into **hydrocarbons** (a misnomer) or **fats, carbohydrates** or sugars and starches, and the vegetable acids.

The following table shows clearly the division of foods into food stuffs.

- Food
  - Inorganic
    - Water
    - Mineral Salts
  - Organic
    - Proteids or Nitrogenous Food
    - Non-nitrogenous Foods
      - Fats or "Hydrocarbons."
      - Carbohydrates or Sugars and Starch.
      - Vegetable Acids.

Water stands second only to oxygen among the necessaries of life. About 70 per cent. of the body consists of water. It is necessary as a food, and also helps digestion by dissolving the digested food. In fact the greater part of food can only be absorbed by the body after it is in solution. Water is also necessary in order to maintain the fluidity of the blood, which contains about 80 per cent. of water, and to assist in the removal of waste matters, especially urea, which is excreted in solution in the urine.

The average person needs from 3½ to 5 pints of water daily in order to supply the loss that is continually going on. About one-third of this is usually taken with the solid food, leaving about 3 pints of water to be drunk per day. In many foods the percentage of water is large, as shown by the following table :—

Green vegetables	90—95	per cent.	water.
Milk	87	,,	,,
Fish	75—80	,,	,,
Lean meat	70—75	,,	,,

Potatoes	75	per cent.	water.
Eggs	74	,,	,,
Cheese	41	,,	,,
Bread	35—40	,,	,,
Butter	17	,,	,,
Oatmeal	16	,,	,,
Peas (dried)	13	,,	,,
Rice	10	,,	,,

Mineral Salts.

These include chloride of sodium, or common salt, chloride of potassium, phosphates of potassium, calcium, and magnesium, and salts of iron. They are essential constituents of food. Thus common salt is the source of the hydrochloric acid present in the gastric juice of the stomach, and which is necessary for digestion. It is also the source of the sodium in bile salts, and is found in every fluid and tissue of the body. The calcium or lime salts are necessary to build up the skeleton: they are contained in most foods, especially milk and cheese. Phosphorus is an indispensable constituent of bone and brain, and the salts of iron are necessary to supply the iron present in the haemoglobin of the red corpuscles.

Nitrogenous Foods or Proteids.

Nitrogenous foods are conveniently arranged in three classes as follows:—

	True Proteids.	*Albuminoids.*	*Secondary Albumins.*
Animal.	Albumin	Gelatin	Albumoses
	Fibrin	Ossein	Peptones
	Globulin	Chondrin	
	Syntonin	Keratin	
	Myosin		
	Casein		
Vegetable.	Gluten		
	Legumen		

The True Proteids.

Albumin constitutes nearly the whole of the solids in the white of eggs and one-third of those in the yolk, the remainder being fat. The average composition of albumin may be taken to be—Carbon, 54 per cent.

Carbon,	54	per cent.
Hydrogen	7	,, ,,
Oxygen	22	,, ,,
Nitrogen	16	,, ,,
Sulphur	1	,, ,,

with small traces of phosphorus. The other members of the group of true proteids have practically the same composition. Albumin is, without doubt, the most important of all the food substances. It is the essential constituent of that substance, called protoplasm, which is described as the physical basis of life. It is soluble in water, precipitated by alcohol, and coagulated by heat.

Fibrin, together with *serum albumin* and *serum globulin*, is present in blood-plasma or, speaking more accurately, a substance is present in blood-plasma which forms fibrin under certain conditions, thereby causing the blood to clot.

Myosin, or muscle albumin, constitutes the bulk of dead muscle. It is coagulated by heat, like albumin, but differs from that substance by being insoluble in water and readily soluble in a 10 per cent. solution of common salt. From this solution myosin may be obtained as a flocculent white precipitate by adding it to a large quantity of distilled water.

Casein is the chief nitrogenous constituent of milk, which also contains some albumin. It is not coagulated by heat, but rennet (pepsin and acid) or free acids readily cause coagulation.

Gluten is the nitrogenous constituent of wheat flour; its elements are present in the seeds of most cereals, and, like albumin and myosin, it is coagulated by heat. The result, therefore, of cooking any food containing either of these three nitrogenous principles will be to coagulate the proteid constituent and render it insoluble in water or dilute acids.

Legumen is found in peas, beans, and lentils. It resembles casein in many respects, being coagulated by acetic acid or by rennet.

The Albuminoids. These bodies contain about 18 per cent. of nitrogen, and so are richer in this element than the true proteids. They are, however, much less nutritious and cannot wholly replace them in a diet. All these bodies, **gelatin**, **ossein**, **chondrin**, and **keratin** are obtained from cartilage, bones, and connective tissue by prolonged boiling. They are easily soluble in warm water, and in many of their reactions they resemble the true proteids.

The Extractives. These constitute a class of nitrogenous bodies about which very little is known. They are contained in meat and appear to act as stimulants to digestion, especially when accompanied by one or more of the albuminoids. Beef tea, in the form in which it is usually prepared, is little more than a solution of these substances. and owes its beneficial action to them.

Digestion of nitrogenous foods. The proteids are attacked by the acid gastric juice in the stomach, and the alkaline pancreatic juice in the small intestine. The digestive ferments, pepsin and trypsin respectively, contained in these juices, convert the proteids into **peptones, albumoses** being an intermediate stage in the process. Peptones differ considerably from proteids, not being precipitated by boiling, or acids, or alkalies. Their most important property is their *diffusibility*, *i.e.* they are able to pass through a membrane from a solution rich in them to a solution in which they are present in small quantities only. As soon as the proteids are converted into peptones in the stomach or the small intestine they will, therefore, rapidly pass through the membrane lining these organs, and be absorbed into the blood vessels and lymphatics which lie on the other side. Partly digested foods, containing variable quantities of peptones and albumoses are often prepared for invalids, but their use has not given quite such satisfactory results as were anticipated.

Functions of nitrogenous foods. Most of the tissues and organs are largely composed of nitrogen. It was formerly thought that in performing its work every organ in the

body consumed a certain portion of its own substance, *i.e.* every organ worked at the expense of its own material. Liebig argued from this that nitrogenous food should be supplied in direct ratio to the actual work done, because the muscles, which do the work, are composed mainly of nitrogenous material. If this theory were true it should follow that the waste nitrogen in the form of urea should also be proportional to the amount of work done, but this has been proved **not** to be the case. Voit has shown that the amount of waste nitrogen excreted is proportional to the amount taken in the food. The modern view upon this subject is that, in doing their work, the muscles and the various organs of the body consume fats and carbohydrates as fuel, forming CO_2 and water as waste products. While they are at work a certain amount of their own material become worn out, just as the working parts of a steam-engine become worn by work and require renewal. It is the function of the nitrogenous food to renew and repair these worn out parts. It is important to remember that the quantities of proteids required for perfect health are practically identical for the same individual whether idle or at work. Of course a big, muscular, hard-working man will require more proteid material than a smaller man who leads a sedentary life, because he has larger muscles to keep in repair.

Nitrogenous foods are required not only for the repair and renewal of old tissues but also for the formation of new, so that in cases where the muscles are being developed, as in judicious training, or in recovery after a long illness, an increase in nitrogenous food will be an advantage, but such increase should take place gradually as the muscles increase in bulk.

The true proteids are practically of equal value, and so may replace each other in a diet. The animal proteids have the advantage over those of vegetable origin by being more easily and rapidly digested. On the other hand, when an excess of meat is eaten, poisonous alkaloidal substances called **ptomaines** may be formed during digestion. Excess of nitrogenous food of any kind causes an accumulation of waste products in the blood; this interferes with

the work of the liver and kidneys, and tends to the development of gout, or liver and kidney diseases. The wealthier classes undoubtedly eat far too much meat.

The **albuminoids** cannot altogether replace the true proteids in a diet, but they may substitute a certain amount of the necessary nitrogenous food. Gelatin appears to be easily oxidised in the body and seems to have the power of preventing the excessive tissue waste that may take place in acute diseases. It is given in jellies or in broth or soup. It is probable that these substances cannot *replace* or *repair* the tissues, but they may prevent excessive waste.

The proportion of proteids present in some common foods is:—

Cheese	28 per cent.	Eggs	13 per cent.
Lentils	24 ,, ,,	Oatmeal	13 ,, ,,
Peas	22 ,, ,,	Eel	12 ,, ,,
Beef	21 ,, ,,	Sole	12 ,, ,,
Mutton	18 ,, ,,	Bread	8 ,, ,,
Fish	14 ,, ,,	Milk	5 ,, ,,

Fats.

The fats, sometimes improperly called hydrocarbons, are compounds of glycerine with certain organic acids, such as oleic, stearic, and palmitic acids. Thus, olein is the fat composed of oleic acid and glycerine, stearin the compound of stearic acid, and palmitin and butyrin the fats containing palmitic and butyric acids respectively. They contain no nitrogen, but are made up of carbon, hydrogen, and oxygen, the oxygen being insufficient in quantity to combine with all the hydrogen and form water; or putting it in another way, the molecule of any of these fats contains less than half as many atoms of oxygen as hydrogen. Their formulae are rather complicated, thus:—

Olein $C_3H_5(C_{18}H_{33}O_2)_3$
Palmitin $C_3H_5(C_{16}H_{31}O_2)_3$
Stearin $C_3H_5(C_{18}H_{35}O_2)_3$
Butyrin $C_3H_5(C_4H_7O_2)_3$.

They are neutral bodies, without colour or taste when pure, and insoluble in water, but soluble in alcohol. When heated with alkalies such as potash or soda, they are decomposed, glycerine being set free and a soap formed by the combination of the fatty acid with the alkali.

Olein is a liquid at the ordinary temperature of the air, but the other fats are solids. The ordinary fats in food contain varying proportions of stearin, palmitin, and olein, and their relative hardness or softness depends upon the relative amounts of these constituents. Bacon fat is less solid than beef fat, and beef fat than mutton fat, because it contains a larger proportion of oleic acid. Olein and palmitin may be obtained from plants or animals, stearin from animals only.

Digestion of fats. The fats are unacted upon by the saliva and gastric juice, and pass through the stomach unchanged. In the small intestine they are **emulsified** by the pancreatic juice and the bile. This emulsification simply consists in breaking up the fat into very tiny globules, which remain suspended in the liquid and do not run together again. If oil is shaken up briskly with water it is broken up into small globules, but these collect again on standing. By first adding a little carbonate of soda to the water, and then shaking up with oil, a much more permanent effect is produced, and the milky fluid thus obtained may be allowed to stand for some time without any of the oil running together again. The emulsification of fats by the bile and pancreatic juice is still further

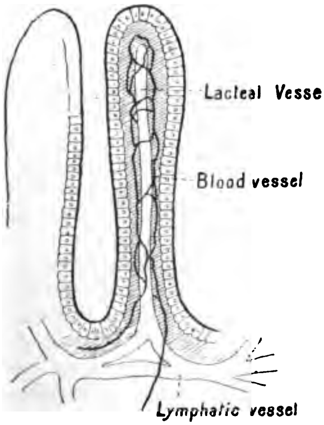


Fig. 13.—A Villus (Magnified).

increased by the chemical change that the pancreatic juice causes the fats to undergo. It acts upon a very small portion of the fat, and changes it into glycerine and a fatty acid.

$$\underset{\text{Olein}}{C_3H_5(C_{16}H_{31}O_2)_3} + 3H_2O = \underset{\text{Glycerine}}{C_3H_5(OH)_3} + \underset{\text{Oleic acid.}}{C_{16}H_{34}O_2}$$

The fatty acid unites with the alkaline salts of sodium that are present and form a soap, which greatly increases the power of the pancreatic juice to emulsify fats.

The inner surface of the small intestine is covered with a great number of tiny projections like the fingers of a glove. These projections are called *villi* (see fig. 13). On the outside of each villus is a layer of columnar epithelium, and inside these are three kinds of vessels—an artery, a vein, and an irregular vessel or space called a **lacteal.** This lacteal is connected with a vessel running beneath the mucous membrane. This is called a lymphatic vessel and is filled with a fluid called lymph.

The emulsified fat passes through the epithelium covering the villi, and makes its way into the lacteals. Shortly after a meal, therefore, the lacteals are filled with a milky fluid which contains fine globules of fat. This milky fluid is called **chyle.** The chyle passes from the lacteal vessels into the lymphatic vessels, and finally enters the blood stream. The animal fats are more easily digested and absorbed than the vegetable.

Functions of fatty foods. The fats are gradually oxidised to carbon dioxide and water in the tissues, and heat and energy are produced. The fats, besides being the chief source of the bodily heat and energy, serve to repair and renew the fatty tissues; moreover, they seem to exert some beneficial influence upon the digestion and assimilation of other foods. This is possibly due to the fact that they promote the flow of bile and pancreatic juice. For the same reason the presence of fats in a diet assists the excretory functions of the intestine. As the fats are the chief source of heat and energy it follows that the harder the work to be done and the colder the surroundings, the more fat is required in the diet. Practical experience has

caused the natives of cold countries to adopt fat and oil as their chief food.

The chief foods containing fat are:—

Butter	contains	85	per cent.	fat
Bacon	,,	73	,,	,,
Goose	,,	45	,,	,,
Pork	,,	34	,,	,,
Eel	,,	29	,,	,,
Cream	,,	27	,,	,,
Cheese (varies)	,,	25	,,	,,
Eggs	,,	12	,,	,,
Salmon	,,	7	,,	,,
Oatmeal	,,	6	,,	,,
Milk	,,	4	,,	,,
Peas	,,	2	,,	,,
Sole	,,	½	,,	,,

Carbohydrates.

Carbohydrates are so called because they consist of carbon, hydrogen, and oxygen only, and the two latter elements are always present in the same proportion as they are in water, *i.e.* there are two atoms of hydrogen to every atom of oxygen. The group includes the various starches and sugars, cellulose and gum. They are mainly of vegetable origin although there is a sugar called lactose in milk, and the liver contains a starchy substance called glycogen.

The carbohydrates are divided into three classes:—

1. Glucoses, common formula $C_6H_{12}O_6$
2. Sucroses, ,, ,, $C_{12}H_{22}O_{11}$
3. Amyloses, ,, ,, $C_6H_{10}O_5$.

Glucose, or **grape sugar**, also called dextrose, exists in nature in grapes and other fruits, and in honey. It is also found in small quantities in the blood. It is prepared in

large quantities by boiling starch with dilute acids, or by the action of malt on starch. Thus—

$$\underset{\text{Starch}}{C_6H_{10}O_5} + H_2O = \underset{\text{Glucose}}{C_6H_{12}O_6}$$

When cane sugar is boiled with dilute acids it is converted into a mixture of dextrose and laevulose. Laevulose is a sugar with the same formula as dextrose, but its solution has a different action on polarised light

$$\underset{\text{Cane sugar}}{C_{12}H_{22}O_{11}} + H_2O = \underset{\text{Dextrose}}{C_6H_{12}O_6} + \underset{\text{Laevulose}}{C_6H_{12}O_6}$$

This mixture of dextrose and laevulose is called "invert sugar." Glucose is soluble in water, and the solution is capable of undergoing direct fermentation when under the influence of yeast; the products of the fermentation being alcohol and carbon dioxide

$$C_6H_{12}O_6 = \underset{\text{Alcohol}}{2C_2H_6O} + 2CO_2.$$

Sucrose or **cane sugar** is the sugar in common use. It exists in large quantities in the juice of the sugar cane and the sugar maple. A similar sugar is obtained from the beetroot. Sucrose is a crystalline solid, soluble in water, and much sweeter than glucose. Boiling with dilute acids converts it into dextrose and laevulose; and a similar change goes on in the process of digestion.

Two other sugars, **maltose** and **lactose**, belong to this group and have the same formula as cane sugar. Maltose is produced by the action of diastase—a ferment present in malt—upon starch.

$$2\,C_6H_{10}O_5 + H_2O = C_{12}H_{22}O_{11}.$$

It is fermentable with yeast, being converted into carbon dioxide and alcohol. Lactose, or sugar of milk, is less soluble than any of the above, and is not directly fermentable.

The Amyloses. The most important member of this group is **starch.** Most vegetable foods contain starch in the form of tiny granules which have a slightly different appearance according to the source, *e.g.* wheat, rice, sago, potato, etc. In its uncooked state a starch granule is very

indigestible because it is enclosed in a covering of cellulose. When cooked, however, the cellulose coat bursts and the starch is set free. To make a solution of starch, therefore, it is necessary to use hot water (above 70°C.). A solution of starch combines with iodine to produce a beautiful blue compound, the formation of which constitutes a most reliable and simple test for starch.

Fig. 14.
STARCH GRAINS.

If heated to about 160°C. with a small quantity of dilute sulphuric acid starch is converted into **dextrin**—a gum-like substance—and, if the action is carried further, into grape sugar. Diastase—a ferment formed in germinating grain—converts it into dextrose and maltose.

Digestion of Carbohydrates. Cooked starches, gums, dextrin, and the various kinds of sugars are converted into grape sugar. This change is commenced by the saliva while the food is in the mouth, and is completed by the pancreatic juice in the small intestine.

$$\underset{\text{Starch}}{C_6H_{10}O_5} + H_2O = \underset{\text{Grape sugar}}{C_6H_{12}O_6}$$

The grape sugar, in solution in water, passes through the walls of the small intestine into the blood vessels. The veins from these parts are collected together into one large vein, called the **portal vein**, which enters the liver. The liver prepares a substance called **glycogen** or "liver starch" from the sugar which is thus brought to it. It is able to re-convert this glycogen into sugar when the need arises, and thus keeps the amount of sugar in the blood practically constant.

Uses of Carbohydrates. The uses of carbohydrates are (1) the production of heat and energy by their oxidation in the tissues, and (2) the formation of new fatty tissues. They are inferior as foods to the fats, but, owing to their cheapness, they form a very important part of the diet of the poor. The fact that they are able to directly form

fatty tissues seems to be proved by indisputable evidence. Fowls and geese are fattened for the market on foods consisting mainly of carbohydrates, and it has also been observed that the negroes on the sugar plantations grow fat during the sugar harvest. By direct experiments with animals it has been proved that the fat supplied in the food was not sufficient to account for all the fat stored up in the body.

The following table shows the percentage of starch in some common foods :—

Tapioca, Sago	nearly pure starch.	Maize meal	65 per cent.
Rice	79 per cent.	Oatmeal	63 ,, ,,
Arrowroot	72 ,, ,,	Peas	59 ,, ,,
Barley flour	69 ,, ,,	Wheat bread	50 ,, ,,
Wheat flour	66 ,, ,,	Potatoes	20 ,, ,,

Vegetable Acids.

These acids appear to be essential to the well being of the body. They are converted into carbonates in the system which tend to preserve the alkalinity of the blood. They exist in fresh vegetables and fruit, and probably in fresh meat and milk, chiefly in combination with sodium and potassium. If these articles are withheld from the diet for a length of time the disease known as scurvy is produced from the general lowering of the vitality. This disease used to be very common among sailors on long voyages, but it is rarely met with now because the provision of fresh vegetables, even potatoes, is sufficient to prevent its occurrence. Lime juice, which is a solution of citric acid and potassium citrate, entirely prevents and cures the disease.

The chief vegetable acids are :—

Malic acid,	contained in	apples,
Citric acid,	,,	lemons and limes,
Tartaric acid,	,,	grapes,
Oxalic acid,	,,	rhubarb,
Acetic acid,	,,	vinegar.

Infants who are fed exclusively upon condensed milk or preserved foods are sometimes found to be suffering from scurvy. The disease is usually associated with rickets, and is cured by feeding with fresh milk and fresh foods.

Potential Energy in Food.

The exact chemical changes or metabolism that food undergoes in the tissues of the body are still unknown, but the result is that the complicated molecules of which it is composed are broken up into simpler molecules, a change accompanied by the evolution of energy. In plants the opposite changes are brought about, the simpler molecules being rearranged and built up into more complicated ones. By means of carefully constructed apparatus it has been found possible to measure the relative amounts of heat that are developed by burning equal quantities of various foods. The figures thus obtained are not of any great practical value because the different food stuffs have different uses and are not mutually replaceable; moreover they are not in all cases broken down in the body in the same way as they are experimentally in the laboratory. The following are the relative numbers obtained in this way:—

Proteids	145	Potatoes	164
Lean beef	197	Bread	169
Fat	378	Cane Sugar	131
Milk (human)	188	Starch	138

A certain deduction (28, about) must be allowed from the number representing proteid material, because the nitrogen is eliminated by the body in the form of urea, which is capable of further oxidation in the laboratory.

DIET.

It is obvious from the functions of nitrogenous foods that they are indispensable in a diet. The body would quickly wear away without them because no repairs to its vital structures would be possible. On the other hand, a diet consisting of proteids, salts, and water is rapidly destructive of healthy action, and would be equally

unsatisfactory in the end, although the body would probably be able to live for a longer time.

Proteids and some non-nitrogenous food with salts and water will support life indefinitely if the two are present in the proper proportions. The similarity in the functions of the carbohydrates and the hydrocarbons would lead to the conclusion that they would be mutually replaceable in a diet, but in practice the contrary is found to be the case. A diet devoid of carbohydrates gives unsatisfactory results except under conditions of great cold or very hard work, while the total deprivation of fat from a diet leads quickly to loss of health and vigour.

De Chaumont sums up the principles of diet as follows:—(1) No single nutritive principle whether nitrogenous or non-nitrogenous can support life except for a very short time. (2) Life may be supported upon one nitrogenous and one non-nitrogenous principle for a long time, but for a permanency salts would require to be added. Thus proteids and fats, or proteids and starches will support life. (3) For the best forms of diet, both fats and carbohydrates are needed in addition to nitrogenous matter, and in all probability both starch and sugar are necessary. A due admixture of more than one form of nitrogenous principle is beneficial.

Obviously the actual quantity of food that is necessary will vary greatly according to the climate, age, sex, the natrue and amount of the work that has to be done. Cold climates or additional work demand an increase in all kinds of food, but especially fats and carbohydrates. Women are said to need generally one-tenth less food than men; but if such is really the case it is probably only due to the fact that their work is of a much lighter character. With regard to age, it is generally considered that a child of ten requires half as much, and a child of fourteen quite as much as a woman. Old people require less proteids and rather more fat than the young or middle aged.

It is found that the average adult loses by the lungs, kidneys, skin, and bowels about 300 grains of nitrogen and about 4700 grains of carbon in 24 hours. This loss must be made good by the food supplied. If too much

nitrogen or too much carbon is supplied the diet is said to be **wasteful** or **unbalanced.** For example, if a man had to live upon bread alone, one ounce of which contains 120 grains of carbon and 5½ grains of nitrogen, he would be obliged to consume about 54 ounces, in order to obtain the necessary amount of nitrogen, and this would contain about 6400 grains of carbon, or 1700 grains too much. Again, in one ounce of beef there are 60 grains of carbon and 10 grains of nitrogen. If this formed the sole article of diet it would be necessary to eat 78 ounces in order to provide 4700 grains of carbon, and this would mean 780 grains of nitrogen, or more than twice as much as is necessary. By mixing the above articles of food it is possible to arrange a diet to contain roughly 300 grains of nitrogen and 4700 grains of carbon. Thus—

	Nitrogen.	Carbon.
32 oz. of Bread ..	176	3840
14 ,, Beef ..	140	840
Total	316 grs.	4680 grs.

The food stuffs are found to have the following composition (when dried):—

One ounce (dried).	Nitrogen.	Carbon.
Proteids	70	210
Fats	—	335
Carbohydrates (average) ..	—	185

From the above figures certain **standard diets** have been compiled. The various authorities differ somewhat as to the exact amounts that are necessary, and it is evident that no hard and fast line can be drawn for all people, differing as they do, in physique and activity. A standard diet may be defined as a theoretical allowance based upon the assumption that the average adult of 150 lbs. needs food containing 307 grains of nitrogen and 4700 grains of carbon. The amounts of food as stated in the table below

Another important use of these tables is in the calculation of the amounts of various foods that are necessary in a diet. Suppose, for instance, a diet is to consist of meat, bread, and butter, and it is required to know how much of each is to be supplied.

Let $x =$ the number of ounces of meat required
$y =$,, ,, ,, bread ,,
$z =$,, ,, ,, butter ,,

x oz. **meat** contains $\frac{20 \times x}{100}$ oz. proteids and $\frac{8 \times x}{100}$ oz. fats,

y oz. **bread** ,, $\frac{8 \times y}{100}$ oz. proteids

and $\frac{50 \times y}{100}$ oz. carbohydrates,

z oz. **butter** contains $\frac{85 \times z}{100}$ oz. fats.

$$\text{Total proteids} = \frac{20x}{100} + \frac{8y}{100}$$

$$= 4\tfrac{1}{2} \text{ oz. for ordinary diet} \quad \ldots.(1)$$

$$\text{Total fats} = \frac{8x}{100} + \frac{85z}{100}$$

$$= 3\tfrac{1}{2} \text{ oz. for ordinary diet} \quad \ldots.(2)$$

$$\text{Total carbohydrates} = \frac{50y}{100}$$

$$= 14 \text{ oz. for ordinary diet} \quad \ldots.(3)$$

From equation (3) it is evident that $y = 28$ oz.

Equation (1) then becomes

$$\frac{20x}{100} + \frac{8 \times 28}{100} = 4\tfrac{1}{2}.$$

$$\therefore\ 20x + 224 = 450$$

$$\therefore\ x = 11 \text{ oz. (about).}$$

Equation (2) now becomes

$$\frac{8 \times 11}{100} + \frac{85\,z}{100} = 3\tfrac{1}{2}$$

$$\therefore \cdot 88 + 85\,z = 350$$

$$\therefore \quad z = 3 \text{ oz. (about).}$$

Therefore the diet should consist of 11 ounces of meat, 28 ounces of bread, 3 ounces of butter, and about 3 pints of water.

Many students will probably find the solution of the necessary equations rather beyond them, and so an alternative method is given below. The composition of the common foods should be learned in grains of carbon and hydrogen per ounce, viz.—

	Carbon (in grains).	*Nitrogen* (in grains).
In 1 oz. milk	30	3
,, 1 oz. egg	70	10
,, 1 oz. meat	65	13
,, 1 oz. butter	315	—
,, 1 oz. cheese	160	25
,, 1 oz. bread	110	6
,, 1 oz. potatoes	50	1
,, 1 oz. oatmeal	175	9

Suppose it is required to solve the above example without the use of equations. Looking out the compositions in the table it is found that

1 oz. meat	contains	65	grs. carbon and	13	grs. nitrogen	
1 oz. bread	,,	110	,, ,, ,,	6	,,	,,
1 oz. butter	,,	315	,, ,, ,,	0	,,	,,
		490		19		

Therefore if one ounce of each were supplied in a diet there would be altogether 490 grains of carbon and 19 grains of nitrogen.

Now it will be remembered that a diet **must** contain 4700 grains of carbon and about 300 grains of nitrogen. The next thing is to alter the amounts of the three foods until the total number of grains of carbon is about 4700 and the nitrogen amounts to about 300. A few trials are

generally sufficient, and students should practice making up several diets in this way.

In the above example the quantities will be found to be

11 oz. meat contains	715	grs. carbon	and	143	grs.	nitrogen
28 oz. bread ,,	3080	,, ,,	,,	168	,,	,,
3 oz. butter ,,	945	,, ,,	,,	0	,,	,,
Total	4740			311		

Examples of diets. An average daily diet for a child between eight and fourteen years may be about 6 ounces of meat, 14 ounces of bread, 6 ounces of potatoes and 9 ounces of milk, together with small quantities of butter, fresh vegetables, and tea or coffee. For adults a good diet would be 1 pound of bread, half a pound of meat, 4 ounces of fat (or 5¼ ounces of bacon), 1 lb. of potatoes, half a pint of milk, 4 ounces of eggs, and 2 ounces of cheese. Another generous diet may be made up as follows: —9 ounces of meat, 18 ounces of bread, 16 ounces of potatoes, 16 ounces of milk, 2 ounces of butter or dripping, and 3 ounces of oatmeal. To each of these diets must be added the necessary amount of water either as such or in the form of tea, coffee, or other beverages.

A mixed diet, consisting of a judicious mixture of animal and vegetable food, appears to afford the greatest nourishment in the least bulk, and to produce the highest intellectual and physical vigour. Variety in food is also of the utmost importance as sameness spoils the appetite while variety improves it. This fact is not sufficiently borne in mind in the feeding of infants, and probably many cases of impaired appetite and digestion may be attributed to the common failure to realise it. The value of several of the vegetable foods is not yet recognised by our working classes. They are not only valuable foods but also have the advantage of being cheap. As Parkes says, "The labouring man, by ringing the changes on oatmeal, maize, peas and beans, rice and macaroni, to which may be occasionally added cheese and bacon, may bring up his children as well nourished as those of the richest people, and at a small cost. Oatmeal, the most nutritious of the

cereal grains, and formerly the staple food of our finest men, Indian meal, peas and beans, and rice are far less used by our poorer classes than should be the case."

Excess or deficiency of food. Taken in excess, **proteids** cause an excessive quantity of urea and uric acid to appear in the urine, and, unless this elimination is aided by active muscular exercise, enlargement of the liver, with more or less dyspepsia, diarrhoea, or gout, will result. If the powers of assimilation be still further overtaxed, unchanged albumin passes by the kidneys. A deficiency of proteids leads to loss of muscular strength, mental debility, and general prostration if the deprivation is sudden, whilst the elimination of urea is always markedly diminished. If a moderately insufficient amount of proteids is habitually taken the muscles decrease in size and the strength becomes less until equilibrium is restored.

Excess of **fats** or **carbohydrates**, if digested, causes the accumulation of fat in the tissues, but more often fermentative changes are set up in the alimentary canal, resulting in biliousness, acidity, and dyspepsia. On the other hand, a deficiency of these foods results in general mal-nutrition. The absence of fat from a diet probably predisposes to such diseases as tubercle in children and young people, and this explains the striking improvement that often follows the administration of cod-liver oil.

Digestibility of food. As a general rule it may be stated that proteids and fats of animal origin are much more easily digested than those obtained from vegetables. Carbohydrates do not differ greatly in digestibility, but white bread, rice, tapioca, and arrow-root are among the most digestible.

Examples of Foods.

Milk is a liquid consisting of emulsified fat, proteids, salts, carbohydrates, and water, and having a specific gravity of 1032 (water being 1000). It is the only food that contains in itself the proper proportion of nitrogen and carbon, and is therefore called a perfect food. Practical

experience bears out such an inference because it is the sole nourishment provided for the young of the higher animals, and, moreover, it will maintain adults in perfect health for an indefinite length of time. With regard to its composition it is important to notice that it contains representatives of the four great food classes—proteids, fats, carbohydrates, and salts, as well as water. The average composition of cow's milk is given below, and, for the sake of comparison, the corresponding constituents of human milk are given at the same time :—

Milk.	Water.	Sugar.	Proteids.	Fats.	Salts.
Cow's	87	4·5	4	3·8	·7
Human	87	6·5	2·2	4	·3.

It will be observed that human milk contains more sugar but less proteids and salts than cow's milk—hence the general rule of diluting the latter and adding a little sugar when preparing food for infants. The sugar in milk is called lactose, or milk sugar, and it is advantageous to use this kind when sweetening food for infants. When milk is allowed to stand, about 10 per cent. of its volume of cream should rise to the top. The cream consists of the greater part of the fat, with a small amount of the other constituents. The liquid left after skimming the milk is called skim milk, and contains casein, milk sugar, and salts; it forms an excellent drink for children. By adding rennet or a very weak acid to milk it is separated into a solid called the curd, and a clear liquid called whey. The curd consists of coagulated casein with the fat and some of the sugar and salts, the whey contains lactose and salts.

When milk is boiled the albumin is coagulated and collects on the top in the form of skin. At the same time other rather obscure changes are brought about which cause it to possess an altered flavour. The most important result of boiling milk is the destruction of all kinds of disease germs and ferments.

Condensed milk should never be used for infant's food where it is possible to obtain cow's milk. There are two kinds of condensed milk, viz. :—(1) that to which cane sugar has been added, and (2) the unsweetened brands. In

preparing both the milk is concentrated by gentle boiling to one-fourth of its original volume. If cow's milk is unobtainable, the unsweetened brands should be used.

Diseases conveyed by milk. As a vehicle of contagion of certain diseases it is very probable that milk is, to some extent, innocent of many of the charges that are brought against it. In our present state of knowledge, however, and in the present lax system of dairy inspection, it is certainly advisable to avoid risk by actually boiling the milk for three or four minutes. It seems to be proved that scarlet fever, foot-and-mouth disease, and possibly diphtheria, may be directly transmitted from the cow. In addition to this danger there is always the possibility of (1) accidental contamination from an outside source, such as may happen when scarlet fever or diphtheria occurs at the dairy or at the house of one of the work people, and (2) the washing of the cans with water containing the germs of cholera or typhoid fever, or the actual adulteration of the milk with such water.

Sour milk is liable to cause sickness and diarrhoea in children, and, under some conditions, the parasitic disease of the mouth known as thrush.

In those epidemics of scarlet fever which have been traced to milk it is usually found that the milk has been infected through human agency by a previous case of the disease at the farm or dairy. A milk epidemic is characterised by the suddenness with which it makes its appearance, the sufferers being usually attacked at about the same time. The houses at which infection has occurred will be found to have received milk from the same dealer.

It has also been proved that the milk of tuberculous cows may convey that disease to animals, and it seems possible that it may affect human beings similarly, although Koch has recently made a definite statement to the contrary. Still more recently De Jong of Leyden has announced, as a result of his experiments, that cattle form a dangerous source of infection to men, and that tuberculosis in cattle requires more rigid measures than were formerly thought necessary.

Adulterations of Milk. The specific gravity of milk is about 1030, being heavier than water because it contains various solids dissolved in it. The cream which rises to the top of the milk after it has stood for some hours is the lightest part, being lighter than water. From these two facts it is obvious that if water is added the specific gravity of the milk becomes **lowered**, while by removing the cream the specific gravity would be **raised**. Therefore a sample of milk with a specific gravity of 1030 may be raised to 1032 by removing a sufficient quantity of its cream, and then reduced to 1030 again by adding water. This double process—the removal of cream and the addition of water—is the chief fraudulent manipulation to which milk is now subjected, and it is obvious that the specific gravity alone is of no value as an indication of adulteration. Thus, a low specific gravity may mean that the milk has been watered, or is very rich in cream, and a high reading shows that it has been skimmed or is naturally deficient in fat. When the total amount of solids and the percentage of fat are known, the specific gravity gives much information as to the quality of the milk, *e.g.* if the specific gravity is low and the percentage of total solids and of fat small the milk has probably been watered.

The question whether a given sample of milk is adulterated or not is entirely one of degree. The standard often adopted by analysts as a minimum is—fat 3 per. cent., solids (not fat) 8·5 per cent. (*i.e.* total solids 11·5 per cent.), ash ·62 per cent. Any milk that falls below this standard should be condemned, because, even though it has not been subjected to any manipulation whatever, it is defrauding the consumer.

Another form of adulteration of milk that is becoming more common is the addition of preservatives such as borax, boracic, benzoic and salicylic acids, and formalin. Of these, boracic acid is, perhaps, the commonest. The addition of preservations to milk should be unnecessary if it is properly cooled before it leaves the dairy. Such addition is undoubtedly a grave offence, especially when it is considered that milk is the staple article of diet for our infant population. Boracic acid, for instance, has been shown by continental

observers to deteriorate the blood corpuscles. Moreover, such agents may do much harm indirectly by permitting other than fresh milk to be used.

Eggs, like milk, contain everything that is required for the construction of the body, but they do not form such a perfect food because they are deficient in salts. A hen's egg consists of 70 per cent. of water and 30 per cent. of solid matter. Of the solids, the white is mainly albumin; the yolk contains fat, albumin, and phosphates. Eggs therefore form a very valuable article of diet, being rich in proteids and fat. They should never be over-cooked because a hard boiled egg is particularly indigestible. To be preserved, eggs should be coated over completely while they are fresh with oil, wax, or lard. A stale egg is easily detected by testing whether it will float or not in a solution of two ounces of common salt in a pint of water. A fresh egg sinks in such a liquid.

Cheese is a food rich in nitrogenous matter. Its average composition may be taken to be water 36 per cent., proteids 33 per cent., fats 24 per cent., salts 5 per cent. It is prepared by adding rennet or a little acid to warm milk, whereby the casein is coagulated and rendered insoluble. The curd, consisting of casein with almost all the fat entangled in it, is separated from the whey by straining, salted, then put into moulds and dried by pressure. Cheeses differ among themselves in the proportion of fat that they contain. The poorest—*e.g.* Dutch cheese—are made from skim milk, and are difficult to digest. Cheddar, Cheshire, and some American cheeses, are made from whole milk; to make the richest cheeses, such as Stilton, cream is added to the milk. If fat and ripe, cheese is easily digested, and forms a very valuable food. Toasted cheese is extremely indigestible. Cream cheese, which is the fresh curd moderately pressed, is easily digested.

As a rule cheese is remarkably free from any adulteration. Starch may be added to increase its weight, and in America some cheeses are made from butter-milk, and then oleomargarine is added. They are equal in nutritive value to those made from pure milk, and are more nutritious

than Dutch cheese, but they should be sold as "margarine cheese." The conventional yellow colour of some kinds is given by anatto which is harmless, but sometimes the rind is found to be coloured with injurious pigments.

Butter is the most easily digested, and the most valuable of our fatty foods. It is almost pure fat, containing: fat 84 per cent., proteids 1 per cent., milk-sugar 1 per cent., water 13 per cent. The amount of water in good butter should not exceed 16 per cent., and the fat should not be below 80 per cent. It is prepared by churning cream, *i.e.* violently agitating it in a suitable apparatus. This causes the fat globules to coalesce and form lumps of fat. The butter thus formed is then pressed, to squeeze out some of the water, and salt is added to preserve it. The liquid left behind is called butter-milk, and contains everything in the milk except the fat. It is a valuable food, and should be used by the poor in country places much more extensively than it is. For invalids who are unable to digest fat, it forms an ideal diet, and is also very suitable for children.

The smell and taste of good butter are familiar to most people, and are sufficiently characteristic to form valuable evidence as to its purity. The colour is variable because anatto is often added in order to give it a rich yellow appearance. Its specific gravity at 100°F. usually varies from 911 to 913, and very rarely falls below 910. The fat consists of fatty acids combined with glycerine. Some of these acids—palmitic, stearic, and oleic—are insoluble in water, while the others—principally butyric acid—are soluble and volatile. This fat is the essential constituent of butter.

Adulterations of butter. Any water above 16 per cent. or an excess of salt should be considered an adulteration, as both these constituents increase the weight and decrease the percentage of fat. Usually, however, attention is directed chiefly to the detection of "foreign fats" or "margarine." The presence or absence of foreign fats is determined by methods based upon various differences in chemical and physical properties between them and butter

fat. The most important of these differences are shown in the following summary:—

Butter-Fat.	*Foreign Fats most often used.*
1. Specific gravity at 100°F. not below 910.	1. Specific gravity below 904.
2. Melting point 90°F.	2. Melting point rarely above 82°F.
3. Under the microscope pure butter consists of a collection of small oil globules, with an occasional large one. No crystals are visible in a sample that has not been melted.	3. The large globules are more numerous, and the small ones are not so well defined. Crystals are often visible.
4. Completely dissolves in ether.	4. Not so readily soluble, and a deposit is usually formed.
5. Never contains less than 4·5 per cent. of soluble volatile fatty acids, and usually contains about 6 or 7 per cent.	5. Usually contains less than ·5 per cent., and never more ·75 per cent. of soluble volatile fatty acids.

Margarine, oleomargarine, or butterine. The above table shows the chief differences between butter and these imitations. All imitation butters must, in this country, be sold "as margarine," and in the United States as "oleomargarine." They are manufactured, as a rule, from beef and mutton fats. The fat is freed from connective tissue, as far as possible, and is then finely minced by machinery. It is then passed into large tanks heated by water-jackets to about 39°C.(103°F.). The fat melts to a clear yellow oil, while the water and waste matter sink to the bottom, and a thin scum rises to the top. This is removed by skimming, and the clear oil is run into vessels and cooled down to about 30_0C. The stearin solidifies at this temperature, and is separated from the liquid part by filtering through cotton cloths. The liquid is then pressed, churned with milk to give it the flavour of butter, coloured with anatto, and cooled with ice.

The average composition of margarine is:—

Water, 12 per cent. Fats, 84 per cent. Salts, 4 per cent.

It forms a cheap and very valuable food, and, if prepared from animal fats, it is as nutritious as butter, and practically its equal as a food. It can be produced much more

cheaply than butter, and is sometimes dishonestly sold as such. The convictions obtained in these cases unfortunately have the effect of prejudicing ignorant people against margarine as a food, and prevent, to some extent its general adoption by the poorer classes.

Meat.

The average composition of raw meat is as follows:—Water, 75 per cent. Proteids, 20 per cent. Fats, 5 per cent.

The proteids consist chiefly of myosin, which coagulates after death, causing the so-called "rigor mortis." Meat also contains a fair proportion of salts, chiefly the chlorides and phosphates of potash. As a food it is rapidly digested and easily assimilated.

Characteristics of good meat. The muscle should be firm and elastic, with a bright colour, and the fat firm, with a clear, yellowish-white appearance. Diseased or tainted meat, on the other hand, will pit when pressed by the finger. When pressure is applied only a small quantity of a clear, thin, red liquid should exude. The fluid squeezed from diseased meat is often mucilaginous or mattery-looking. The odour should be faint but pleasant, and there should be no smell of putrefaction or physic. Decomposition often is most apparent in the deeper parts, close to the bone, and may be detected by thrusting a knife deeply into the meat and smelling it as soon as it is withdrawn. Disease is generally indicated by a watery, sodden, and inelastic muscle, and the fat deficient or reddish-yellow and blood-stained. A measly or speckled appearance is also suspicious.

Diseases from meat. If decomposed or putrid meat is eaten it usually gives rise to vomiting, diarrhoea, collapse, and even death. Game and mountain fed mutton, however, seem to be eaten with impunity even when decomposition is far advanced. In some cases very severe symptoms of poisoning have been set up by eating food in which the decomposition is extremely slight, and this is especially the case with sausages, canned meats, and fish.

These effects are probably not produced by the slight decomposition, but by poisonous alkaloids which have been formed by certain bacteria, and the most thorough cooking fails entirely to remove the danger from these poisons. The flesh of diseased animals is a frequent source of illness, although the balance of evidence appears to point to the fact that diseased meat from cattle, sheep, and pigs may be eaten with impunity if thoroughly cooked. There is no reason, however, why diseased meat should be allowed to be used for human consumption, and the sale of it should always be condemned. The diseases of animals which are believed to be transmissible to man include anthrax or malignant pustule, tubercle, and foot and mouth disease. These diseases are undoubtedly more frequently transmitted to man by other means, yet it is important to bear in mind the possibility of such transmission by the consumption of diseased flesh. With regard to the flesh of cattle suffering from tuberculosis it is now advised that the diseased parts only should be destroyed in those cases in which the disease seems to be confined to one part of the body, such as the lungs, the liver, or one set of lymphatic glands. When the disease is more widely spread it is advisable to destroy the whole carcase.

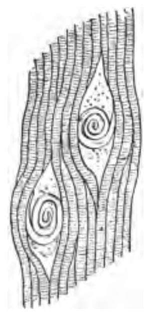


Fig. 15.
TRICHINAE IN MUSCLE FIBRES.

The milk of cows suffering from any febrile disease or disease of the udder, especially tuberculosis, should be condemned. Foot and mouth disease is directly communicable to man by milk, and may fatally affect infants, but all danger is removed if the milk is boiled for five minutes. Parasitic diseases are often conveyed to human beings by imperfectly cooked meat. In beef there may be a parasite called **cysticercus bovis**, which gives rise to a tape-worm in man. In sheep the commonest parasite is the **liver fluke**, or *cervus cornus*, but it rarely affects man. "Measly" flesh from the pig, ox, or sheep is infected by a parasite called the bladder worm, which, when eaten, undergoes a

series of changes resulting in its conversion into a tapeworm. The flesh of the pig is, moreover, commonly affected by a minute worm called **trichina spiralis**, which is only killed by the most thorough cooking. When these organisms enter the alimentary canal of man they set up the dangerous and often fatal disorder known as **trichiniasis**, a disease which is most prevalent where pork is eaten in the form of sausages, ham, etc., either uncooked or very imperfectly cooked.

Vegetable Foods.

These foods usually contain proteids, starch, sugar, and fat in varying proportions, but in most cases the starch or the sugar is very greatly in excess. The only vegetables that contain any important amount of proteids are the pulses—peas, beans, and lentils—which contain over 20 per cent., and some of the cereals—wheat, oats, barley, and maize—containing more than 10 per cent. The proteids present are mainly albumin, legumin, and gluten.

Vegetable foods are usually divided into six classes:—(1) the cereals, (2) the pulses, (3) roots, (4) green vegetables, (5) fruits, (6) edible fungi.

1. The Cereals are grass-like plants whose seeds are used for food; they include wheat, oats, barley, rye, maize, and rice. Their relative composition is shown by the following table:—

	Starch.	*Proteids.*	*Sugar.*	*Fat.*
Wheat	64	15·5	2·5	1·5
Oats	50	15	2·5	5
Barley	63·5	11·5	1·5	1
Rye	62	15	4·5	1·5
Maize	65	14	2	3·5
Rice	80	5	·4	0

From the above table it is seen that all the cereals contain a very large percentage of starch, a moderate proportion of proteids, and variable small quantities of sugar and fat. Maize and oats form the most perfect foods in this class, while rice is the least valuable. The other

points to be noticed are: (1) oats are exceptionally rich in fat; (2) rye is much richer in sugar than the others; (3) rice has the highest percentage of starch, but is poor in everything else.

Wheat contains a large quantity of a substance which changes into gluten when mixed with water. This renders it capable of being made into a coherent dough and then into bread. The other cereals, with the exception of rye, contain too little gluten to be made into bread without mixing first with wheat flour. In the preparation of wheat flour the outside shell may be retained with the flour when brown bread is desired, or separated entirely in the form of bran when the flour is to be used for white bread. The bran undoubtedly contains a large amount of apparently nutritious matter, but it is doubtful whether any of it can be absorbed by the body. It is often useful in cases of constipation, but for habitual use the white bread is the best. A good flour should be white in colour and free from any smell of mould. It is occasionally adulterated with starch from potatoes or rice, but as these starch granules have a different shape when viewed under the microscope their detection is easy.

Bread is made by mixing wheat flour with water, salt, and yeast into a consistent dough, which is allowed to rise in a warm room, and then baked in an oven. The usual proportions are—flour 20 lbs., water 8 pints, yeast 4 oz., salt 2 oz. There is also often added a considerable quantity of mashed potatoes. One hundred pounds of flour will yield, on an average, 140 lbs. of bread. In making bread, the water, which must be warm but not hot, should be divided into two parts, one part twice as large as the other. Dissolve the salt in the larger part, and mix the yeast with the smaller portion. Then mix the two together and add it gradually to the flour, thoroughly kneading the mass until it has formed a uniform consistent dough. This is allowed to stand for four or five hours to rise, and is then made into loaves and baked. The rising of bread is due to the action of the yeast which converts some of the starch into sugar, and the latter into alcohol and carbon dioxide. The coherent

nature of the gluten prevents the escape of the CO_2, which forms little cells in the dough. In the baking the gas expands and enlarges the cells, producing that spongy structure so characteristic of well-made bread. The minute quantity of alcohol that is formed escapes into the air. During the baking certain other changes are produced, including the conversion of a small part of the starch into sugar and dextrin.

"Aerated bread" is now widely used. It is prepared by forcing carbon dioxide into the dough by pressure. It is undoubtedly a cleaner process, and there is no danger of sourness or acidity being produced, but it is claimed that yeast fermentation renders the bread more digestible. Another method of making the bread light is to add some form of baking powder to the flour. These usually consist of sodium bicarbonate and citric or tartaric acid which in the presence of water evolve carbon dioxide. Another plan is to mix the bicarbonate of soda with the flour and add the calculated quantity of hydrochloric acid to the water. Carbon dioxide is evolved when these substances meet, and the residue left is common salt.

Many patent breads are now on the market under the names of "Hovis," "Germ," and "Bermaline." The flour from which these are made differs from ordinary flour in containing the "germ" or the central part of the wheat grain. This part is discarded in the preparation of ordinary flour, but for these patent flours it is specially treated to give it good keeping properties and then mixed with white flour. The result is a bread of a higher nutritive value than ordinary bread.

Hygienically the most important **adulteration** of bread is alum. This is sometimes added to inferior flour, in cooking, so as to check the fermentative action whereby a large amount of glucose is formed, and a discoloured, unpleasant bread results. Alum therefore improves the taste and the colour of the bread, and also to some extent its porosity. When used, it is employed in quantities amounting to about 20 grains to a 4 lb. loaf. No addition of alum should be allowed because it may be injurious to health, and induce dyspepsia, constipation, etc. To detect the presence

of alum in bread, cut some pieces from the centre of the loaf, and allow them to soak in a mixture of 30 c.c. distilled water, 5 c.c. strong solution of logwood, and 5 c.c. of a 15 per cent. solution of ammonium carbonate for a few minutes. Then drain off the liquid and gently dry the bread. If alum is present the bread will show parts stained lavender or violet, while if there is no alum the bread will at first be stained pink and afterwards change to a dirty brown colour.

Mashed potatoes in small amounts favour the fermentation process, and are looked upon as a legitimate addition. When cheap, they are sometimes added in large quantities to increase the weight. Pea or bean flour is also occasionally added in small quantities, but is easily detected by pouring boiling water over the bread or flour, which causes the characteristic odour of the pea or bean to be emitted. Rice flour is sometimes added for the purpose of giving a good white colour to the loaf.

Macaroni and **vermicelli** are both preparations of flour and are rich in gluten. They form excellent foods when cooked with milk, and may be used as substitutes for meat.

Oats contain very little gluten and so are not adapted for bread making. Oatmeal is, however, made into thin cakes by mixing into a paste with water, and then baking. Oatmeal is highly nutritious if well cooked, and when taken with milk in the form of well-cooked porridge it forms as cheap and as perfect a food as can be obtained.

Barley resembles wheat in composition, but its proteids do not form gluten when acted upon by water. It is therefore not suitable for bread making. Pearl barley is the grain after its husk has been removed. When barley is allowed to germinate, or sprout, the starch of the grain is partly converted into grape sugar by a ferment called **diastase**, which is developed within the grain. Germinated barley is called malt. Extract of malt—a treacly fluid obtained from malt—forms a nutritious and useful food for delicate children, because the diastase it contains helps the digestion of starch.

Rye is used in Northern Europe for bread making. It

forms a heavy dark brown bread which easily turns sour, and is rather indigestible. It usually produces diarrhoea in those unaccustomed to it.

Maize also is deficient in gluten and so does not make good bread. It is, however, highly nutritious, like oats, and is a valuable food when made into porridge or cakes. In former days the slaves of the Southern States of North America were fed almost exclusively upon maize, and appeared to flourish upon the diet. **Cornflour** consists of the starch of maize, from which the proteid has been removed. **Hominy** is a similar preparation, but it contains all the original nutriment.

Rice is remarkably poor in proteids, fats, and salts. It is an important starchy food, and when well cooked is easily digested. Experience in the Indian famines clearly shows that any attempt to maintain life on rice alone is but slow starvation.

2. The Pulses. The commonest of these are peas, beans, and lentils. They contain more than 20 per cent. of proteid material, chiefly legumin. They are the richest proteid foods except cheese, and they approach more nearly to perfect foods than any other vegetable. Unfortunately, however, they are rather difficult of digestion, and are often the cause of flatulence. Lentils are the most nutritious, also the easiest cooked and digested. Beans are best eaten before the hilum, or point of attachment, has become dark-coloured, and while they cannot be boiled without bursting their skins. In this condition they are digestible and nutritious and, if combined with fatty foods such as bacon or melted butter, they furnish a complete meal.

3. Roots and Tubers. These are used chiefly for their starch, and to some extent on account of their salts. They include potatoes, carrots, parsnips, beetroots, turnips, and artichokes, all of which contain large quantities of starch and water, while beetroots, carrots, and parsnips contain sugar as well. Arrowroot and tapioca are nearly pure starches derived from the tubers of different plants. Sago is a similar substance obtained from the pith of a palm, and is conveniently included in this class.

Potatoes are easily digested when full grown and properly cooked. Young ones composed of immature cell tissue and unformed starch are indigestible and less nutritious. The value of potatoes lies in the starch and the salts—malates, tartrates, and citrates—they contain. The latter constituents give the potato most valuable antiscorbutic properties. When cooked in the usual way by boiling, most of these salts are lost, it is therefore much better to either boil them in their skins, or, better still to cook them by steaming.

4. Green Vegetables contain very little nutritive material, and are valuable chiefly on account of their salts. In this group are included cabbages, cauliflowers, lettuces, vegetable marrows, tomatoes, etc. They give variety and relish to the food, and act as artiscorbutics in preventing scurvy—a disease that was formerly prevalent among sailors and those classes who were unable to obtain fresh vegetables or fruits. Another rather important use of these foods is due to the cellulose they contain. This is a substance resembling starch, but is indigestible: it is useful, however, in forming a bulk in the intestines, thereby stimulating their movements and preventing constipation. The onion, leek, shallot, etc., possess essential oils which are useful in flavouring food.

5. Fruits are usually rich in salts of potash and vegetable acids. They contain very little nutritive matter, but are valuable on account of their antiscorbutic properties, and are prized chiefly for their taste, which they owe to the above acids associated with more or less sugar and certain ethereal oils. Many of them contain a considerable amount of sugar, and a few—*e.g.* the banana, date, and fig—are nutritious on account of containing starch and sugar. Raw fruit should only be eaten when quite ripe and perfectly fresh. The best time to eat it is at breakfast or between meals. It then promotes evacuation of the bowels, acting as a mild and pleasant purgative. Lime juice and lemon juice contain citric acid and are valuable antiscorbutics. With water they form refreshing drinks, and are useful as antidotes for alkali poisoning.

6. The Edible Fungi, such as mushrooms, contain about

91 per cent. of water and a little nitrogen. They are usually very indigestible, and are of no value as foods.

PRACTICAL WORK ON CHAPTER III.

I. Experiments with Albumin, etc.

1. Separate the white of an egg from the yolk. This may be taken as a sample of albumin. Make notes as to its colour, taste, and smell.

2. Shake some of the albumin with water. It dissolves in the water. Dip a piece of red litmus paper into the solution. The paper turns blue, showing that egg-albumin is slightly alkaline. Warm the solution in a test tube. Note the coagulation of the albumin.

3. Pour some albumin into a test tube (there should be sufficient in the tube to cover the bulb of a thermometer). Place a thermometer in the tube, and warm the albumin by immersing the tube in water in a beaker over the Bunsen flame. Notice the temperature at which the albumin coagulates. This should occur at about 60°C. Test whether the coagulated albumin will dissolve in water. It will be found to be insoluble.

4. **To show the presence of albumin in meat.** Soak a small quantity of finely chopped lean meat in cold water for an hour, then filter the liquid and warm the clear solution in a test tube. The albumin coagulates when heated.

5. **To prepare myosin from meat.** Take the minced meat used in experiment 4. Just cover it with a 10 per cent. solution of common salt and gently warm it by immersing the tube or beaker in water at the body temperature. Shake well and allow to stand for an hour. Then allow the liquid to drop into a large beaker filled with distilled water. The myosin separates out in the form of a flocculent deposit.

6. **Digestion of proteids.** (*a*) Get a fresh pig's stomach from the butcher's, cut it open, and wash it out. Next scrape off the inner coat with a blunt knife and mince it. Put it into a mortar and rub it with some ·2 per cent. hydrochloric acid solution. Leave it in a warm place for two hours. Pour off the clear liquid, and put into it some very small fragments of hard boiled white of egg, and keep it at the temperature of the body. In less than an hour the white of egg will probably have disappeared. It has been changed into peptone by the action of the **gastric juice**. To a small quantity of the liquid add some strong caustic soda solution and one drop of a dilute solution of copper sulphate. A pink colour should be produced. This is a characteristic reaction of peptones. Instead of obtaining the pepsin from the pig's stomach it may be more convenient for students to use a small pinch of solid "pepsin," which is obtainable from chemists. This should be used with the dilute hydrochloric acid, as above.

(*b*) To observe the pancreatic digestion of proteids, obtain a fresh pig's sweetbread, chop it finely, and soak it in a 1 per cent. solution of sodium carbonate (or use a small quantity of pancreatic extract).

Pour off the clear liquid and use part of it to show that it digests fragments of hard-boiled white of egg and converts it into peptone. Keep the other part to show its digestive action on starch.

II.—EXPERIMENTS WITH FATS.

1. **Emulsification of Fats.** (*a*) Pour a few drops of linseed oil into a test tube, and add a little water (about one inch deep). Place your thumb over the end of the test-tube, and shake the contents vigorously. Note the appearance of the emulsion, and put the test tube in a stand for a quarter of an hour. By this time the milkiness will have disappeared, and the oil and the water separated again into two layers. This is only temporary emulsification.

(*b*) Repeat experiment (*a*), but this time add a pinch of carbonate of soda to the water before shaking up. This time the emulsification is much more permanent.

2. **To obtain glycerine and soap from fat.** Put about two teaspoonfuls of pure lard into a porcelain dish, cover it about an inch deep with caustic soda solution, and warm gently. The fat at first floats on the liquid, but slowly disappears. If necessary, add more solution of caustic soda to the mixture. Finally all the oil should have disappeared. Make the contents of the dish quite liquid by adding warm water if necessary, and then add half its volume of a saturated solution of common salt. A curd of soap separates and rises to the top. The liquid beneath contains glycerine.

III. EXPERIMENTS WITH SUGARS.

1. **Grape Sugar.** Add a little glucose to some Fehling's solution in a test tube. Heat in the Bunsen flame, and note that a red precipitate is produced.

2. **Cane Sugar.** Dissolve a teaspoonful of sugar in about a teacupful of water. Add a little of this to some Fehling's solution and warm. No result is obtained, showing there is no glucose present. Put the remainder of the solution into a flask and add to it a few drops of strong sulphuric acid, and boil for about half-an-hour. Then neutralise the acid by adding solution of carbonate of soda, a little at a time until the last drop produced no effervescence. Test the liquid with Fehling's solution and you will find that glucose is now present. This process is known as the "inversion of cane sugar," and the sugars now in solution are called "invert sugar."

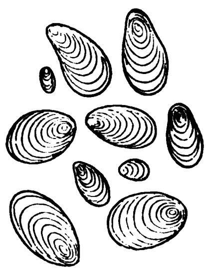


Fig. 16.—STARCH GRAINS FROM POTATO (× 200).

IV. EXPERIMENTS WITH STARCHES.

1. **Microscopic appearance.** (*a*) Potato starch. Scrape the fresh cut surface of a potato very gently with a clean knife, and smear the

milky liquid which collects on the knife upon the surface of a clean microscope slide. The smear should be very thin and must be as uniform as possible. Allow it to dry. Then place one drop of water in the middle of the smear, and lower a clean coverglass carefully upon the drop. Examine with the low power of the microscope. The starch grains, which vary greatly in size, are composed of concentric layers surrounding a darker spot situated near the smaller end of the grain. Make another smear, dry it, and mount it this time in very weak, almost colourless, solution of iodine. On examining this with the microscope you will see that the grains nave stained dark blue.

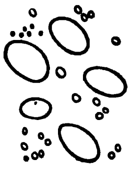


Fig. 17.—Starch Grains from Wheat (x 200).

(*b*) In the same way examine very thin films made of ordinary flour, pea flour, and oatmeal. Draw the grains in each case, and note the differences in appearance.

2. **Solubility.** Shake up a small quantity of starch with water. A milky liquid is produced. Filter this and add to the clear filtrate a few drops of solution of iodine. No blue colour is produced, showing that none of the starch has dissolved. Start again, but this time heat the milky fluid over the Bunsen. Notice that just before the water begins to boil the milkiness disappears and gives an almost transparent liquid. Dilute this and add a few drops of iodine solution. A deep blue colour is produced which is the test by which starch is always recognised.

Fig. 18.—Starch Grains from Pea (x 200).

3. **To convert starch to glucose.** Make about a teacupful of thin starch solution, as above, and add 12 drops of strong sulphuric acid to it. Pour it into a flask or beaker and boil it for about half-an-hour. Then test with Fehling's solution and show that glucose is present in the liquid.

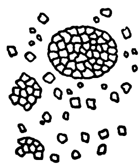


Fig. 19.—Starch Grain from Oat (x 200).

4. **Digestion of starch.** (*a*) To a small quantity of starch solution add a little of your own saliva, and keep the liquid at about the body temperature for about half-an-hour. The liquid bocomes thinner and more watery. Pour a small quantity into another test tube and add iodine solution to it. This time there is no blue colour formed, showing that the starch has disappeared.

Taste the remaining liquid; the sweetness tells you that the starch has been turned into sugar. Show the presence of glucose by means of Fehling's solution.

(*b*) Repeat the above experiment using pancreatic extract instead of saliva, show again that the starch is turned into sugar.

(*c*) Again repeat experiment 4 (*a*) but this time use malt extract. (It is not necessary to keep the liquid warm in this case.) Show that the extract of malt also converts starch to sugar.

MILK.

1. **Microscopic appearance.** Place a drop of milk on a clean microscope slide and carefully lower a cover slip upon it. Examine it with the low and the high powers of the microscope. Note the small rounded globules of fat.

2. **Cream.** Pour milk into a cream tube, which is a simple graduated glass cylinder, until it is filled to the level of the 0 on the scale.

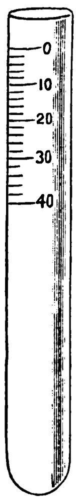


Fig. 20.—CREAM TUBE.

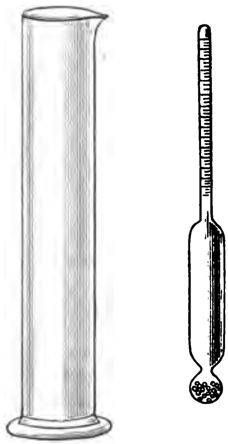


Fig. 21.—LACTOMETER AND GLASS.

Then set it aside for 12 to 24 hours, and read off the level of the bottom of the layer of cream. If the layer of cream extends from the 0 to the 10 on the scale then the cream is 10 per cent., and so on.

3. **Specific gravity.** (*a*) This is determined by means of the lactometer, or by weighing a known volume of milk. The lactometer method is the easier. Fill the glass with milk to within an inch of

the top and gently immerse the lactometer in it. There should be no frothing on the top, and the lactometer must be quite free from the sides, and at rest, when the reading is taken. The level of the milk should be opposite the mark corresponding to 1032 about.

(*b*) Now determine the specific gravity of some skimmod milk. It will be found to be about 1035.

(*c*) Add a small quantity of water to the skim milk, mix thoroughly and again take its specific gravity. It is now below 1035. By adding small quantities of water at a time obtain a mixture with the same specific gravity as the new milk, *i.e.* 1032. This experiment shows that the removal of cream, if balanced by the addition of water, cannot be detected by determining the specific gravity.

Constituents. (*a*) Dilute a small quantity of milk with an equal volume of water, and add a few drops of vinegar, or dilute acetic acid, until a slight precipitate is formed. Then gently warm the liquid (do not boil). Filter. The white solid left on the filter paper is mainly casein.

(*b*) Boil the clear filtrate from (*a*). Any albumin that may be present will be coagulated. Filter this off.

(*c*) Test the clear liquid from (*b*) for sugar by adding Fehling's solution and boiling. If sugar is present a red precipitate will be produced.

5. **Total Solids.** Weigh a small shallow platinum dish with a short glass rod in it. Measure into it 10 cubic centimeters of milk, and weigh again. The gain in weight gives the weight of the milk. Partly fill a beaker with water, put the dish on the top of the beaker, and boil the water. The heat from the steam causes the milk to evaporate. Stir it from time to time with the glass rod in order to break up the skin that forms on the top. When the residue appears dry remove the dish to a hot air oven for three hours, then place in a dessicator until it is cool, and then weigh.

Example.	Weight of dish + glass rod	=	29·416	grammes
	Dish + 10 c.c. milk + glass rod	=	39·728	,,
	Weight of milk	=	10·312	,,
Again	Dish + dry residue + glass rod	=	30·837	,,
	Dish + glass rod	=	29·416	,,
			1·421	,,

Therefore there are 1·421 grammes of solids in 10·412 grammes of milk, or 13·7 per cent.

6. **The Ash**, or mineral matters. Place the dish containing the dry residue on a pipe-clay triangle and heat it gently with a small Bunsen flame. The solid blackens and smokes, but the heating must be continued until nothing but a clean grey ash is left. The glass rod should be used to stir the residue from time to time while the heating is going on. Towards the end it may be necessary to use a larger flame. When only a grey ash remains allow the dish to cool and then

weigh it. Calculate the percentage amount of mineral matter present in the milk.

7. **The fat.** A tube, closed at one end, and graduated to 50 c.c. is used for this estimation. Pour into the tube 10 c.c. of milk and add to it 10 c.c. strong hydrochloric acid. The liquid will now stand at the 20 c.c. mark. Place the tube in a vessel containing sufficient water to cover the 20 c.c. and gradually raise the temperature of the water to boiling point. Let the water boil for five minutes, then remove the tube and allow it to cool for five minutes. Finally cool the tube by allowing cold water from the tap to run upon it. Now fill up the tube to the 50 c.c. mark with ether, cork the tube, and shake it for about one minute, and then set aside for 10 minutes. At the end of this time the ether will have formed a separate layer on the top of the other liquid. The ether has now dissolved the fat out of the milk. Read off the volume of the layer of ether, and remove some sample part of it, say one-third to a clean weighed dish. (There usually forms a brown fluffy layer between the upper and lower layers. In reading the volume of the ether add on three-fourths of this fluffy layer). Place the dish in an oven at 100° C. for 10 minutes and weigh again. By this time the ether has evaporated and left the fat in the dish.

Example. 10 c.c. of milk taken.

Total volume of ether after shaking = 27 c.c.

9 c.c. removed by means of a pipette into a weighed dish.

Wt. of dish = 18·756 grammes

Wt. of dish + fat = 18·880 ,,

·124 ,,

Therefore there are ·124 grammes of fat in 9 c.c. ether

Therefore ,, ,, ·124 × 3 ,, ,, 27 ,, ,,

i.e. = ·372 grammes fat in the 10 c.c. of milk, or 10·312 grammes milk, which is equivalent to 3·6 per cent.

Butter and Margarine.

1. **Microscopic appearance.** Make a smear of butter on a microscope slide and examine it under the miscroscope. Notice that the field is filled chiefly with a great number of tiny round oil globules with clearly defined edges. Amongst them are a few much larger ones which do not vary much in size.

Now examine a smear of margarine in the same way. This time you will find that the small oil globules are much less distinct, and appear to be more crowded together. There is also a greater proportion of the large globules which in this case vary considerably in size.

2. **Preparation of Butter-fat and Margarine-fat.** Nearly fill a small porcelain dish with butter, and place it in a warm place—in an oven, for example, or on a beaker in which some water is boiling—

until the butter is completely melted. Notice that there are two distinct layers: an upper layer of clear yellow fat, and a lower layer of water, salt, and some curd. Carefully pour the upper layer into a dried filter paper folded in the usual way and placed in a filter funnel. Collect the clear butter-fat in a clean dry wide-necked bottle, label it "butter-fat" and cork it up.

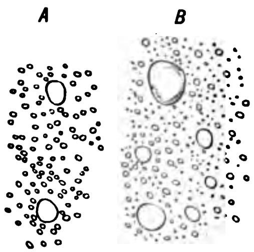


Fig. 22.—A, Butter; B, Margarine.

Prepare a sample of margarine-fat in exactly the same way.

3. **The Melting Point.** Fit up the apparatus as shown in fig. 23. The outer beaker is filled with cold water and immersed in this is a small beaker also partly filled with cold water. Melt the butter-fat by holding the bottle in hot water for a few minutes and then pour a few drops of the melted fat into cold water (if possible iced water should be used). The fat sets into little firm pellets. Press one of these pellets round the looped end of a platinum wire and fasten the wire alongside a thermometer so that the loop of the wire is near the bulb of the thermometer. Immerse the thermometer and wire in the water in the small beaker, and gradually raise the temperature of the water in the outer beaker by means of the Bunsen flame. Continue heating until you see the fat melt, then notice the reading of the thermometer. This temperature should be between 88° and 91° F. Now repeat the experiment, but use margarine-fat instead of butter-fat. The temperature at which the fat melts this time should be about 80° F.

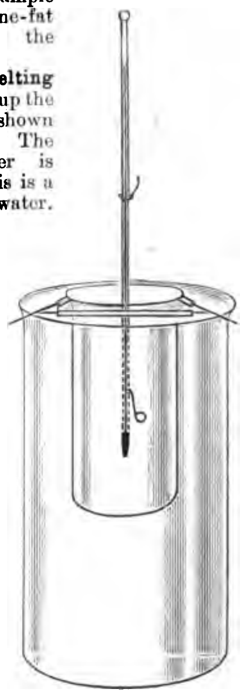


Fig. 23.

4. **The Valenta test.** Pour some melted butter-fat into a clean dry test tube until the fat is one inch deep. Then pour glacial acetic acid into the same tube until it contains two inches deep of the mixture. You have now taken equal volumes of butter-fat and glacial acetic acid. Shake the tube so as to mix the contents, place it in some water in a beaker, and heat the water. While the temperature is rising keep the

contents well mixed by continuous shaking. By means of a thermometer note the temperature at which the contents of the tube forms a clear solution. This should occur at about 91° F.

Repeat the above experiment with margarine-fat. In this case the mixture will have to be heated at about 200° F.

5. **Other Tests.** (*a*) Heat some butter in a platinum dish over a Bunsen burner. A considerable amount of foam is produced which may run over the dish, but the boiling proceeds quietly. Margarine, on the other hand, produces very little foaming when heated, but the process is usually accompanied by a certain amount of noisy spluttering.

(*b*) Place a small quantity of margarine on a platinum spatula and heat it in a flame. When it takes fire blow out the flame and notice the smell of the fumes that arises from the extinguished fat. It has the peculiar odour of burnt tallow. Butter should give off no such smell when treated similarly.

Meat.

1. **Amount of water.** Take about one-third of an ounce of lean beef. Cut it into thin small slices, and arrange these evenly in a weighed porcelain dish. Now weigh the dish containing the meat; the gain in weight will tell you the exact weight of the meat. Place the dish and its contents in an oven at about 220°F. for about three or four hours. Then allow the dish to cool in a dessicator and weigh it again. From the loss in weight calculate the percentage of water contained in lean meat.

2. **Amount of mineral matter.** To determine this, place the dish containing the dried meat on a pipe-clay triangle and heat it with the Bunsen flame. Heat gently at first, but when the meat has become hard and black the heat must be increased. Finally a white ash is all that remains. Cool the dish and weigh it again. Calculate the percentage of mineral matter in lean meat.

Flour.

1. **Its constituents.** (*a*) Measure about two tablespoonfuls of flour into a basin, and add water, small quantities at a time, keeping the mass well stirred with a glass rod until a uniform dough has been obtained. Now tie it in a double muslin bag and gently knead it in a basin of water. The water soon appears milky. After kneading the dough for about 5 minutes pour away the milky water into another vessel and keep it for experiment.

(*b*) Continue the kneading in fresh water, and renew it from time to time until no milkiness is produced. Eventually a sticky, tenacious, and elastic mass is left in the bag. This is **gluten.**

(*c*) Place a little of the sticky substance in a test tube and warm it. Notice that the heat causes it to solidify. Continue the heating,

causing the mass to blacken, showing the presence of carbon, and to give off a gas smelling like burnt feathers, which is a common characteristic of many substances containing nitrogen.

(*d*) Take a little of the milky liquid from (*a*). The milkiness is due to the starch grains. Boil it; this makes it clear. Test the solution for starch by adding one drop of iodine solution.

(*e*) Filter some of the milky liquid from (*a*) and boil the filtrate. A faint precipitate is produced showing the presence of albumin.

(*f*) Place a small quantity of flour in a porcelain dish over the Bunsen flame. It first turn black, but finally a grey ash is left behind. This is chiefly phosphate of potassium.

2. **The amount of gluten.** Weigh out 10 grammes of flour into a dish, and proceed to obtain the gluten from it as above. Spread out the gluten in an even layer on the bottom of a weighed porcelain dish, and dry it in an oven at 215°F. for three hours. Cool the dish and weigh again. Calculate the percentage of gluten in the flour.

3. **Adulterations.** Test for alum in a sample of bread, by the method described on page 77.

CHAPTER IV.

ACCESSORY FOODS.

In the classification of foods given in the previous chapter many substances which enter largely into an ordinary diet have been omitted. These additional substances—sometimes called food accessories—may be divided into condiments and beverages. They possess little or no nutritive value, and are useful chiefly owing to their agreeable taste, smell, or effect on the nervous system. The Germans refer to them as Genussmittel, or "means of enjoyment," as compared with the real foods which are called Nahrungsmittel, or "means of nourishment."

Condiments.

The condiments are substances which are added in small quantities to the food with the object of making it more tasty and palatable, thereby stimulating the secretion of the saliva and gastric juice, and thus aiding digestion. Included in this group are mustard, pepper, salt, ginger, nutmeg, horseradish, cloves, onions, mint, vinegar, parsley, lemon juice, and lime juice. Most of them owe their value to the aromatic oils they contain. In moderation these substances are very useful and serve to give variety to the food, but if indulged in to excess they are injurious, tending to produce exhaustion of the mucous membrane of the stomach and rendering the gastric glands insensible to the stimulus of plain food. The habitual use of condiments tends also to produce a catarrh of the mucous membrane.

Vinegar is, or should be, dilute acetic acid. The best vinegars are obtained from alcoholic liquors by a process of fermentation, which results in their oxidation. There

are three varieties of vinegar in the market—wine vinegar, malt vinegar, and wood vinegar; and the amount of acetic acid varies from 3 to 6 per cent. It is often adulterated by sulphuric acid, which may be detected by the addition of a solution of barium chloride and a few drops of nitric acid. If sulphuric acid is present a white precipitate of barium sulphate will be produced. If taken in excess vinegar is very injurious, especially if it contains sulphuric acid, but in moderate doses it may serve to help digestion.

Pickles have the same advantages and disadvantages as vinegar. Pickled vegetables are hard and indigestible of themselves, but may make appetising an otherwise tasteless dish. If preserved in tins they are liable to contain copper and lead from the cans or the solder. They should always be kept in glass or stone vessels.

Mustard. The pure seed would be acrid and unpalatable, and many adulterants are therefore employed. The mustard in general use consists of a mixture of brown

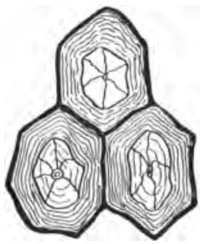


Fig. 24.—Cells of Mustard Seed.

and white mustard mixed with colouring matter, flour, and ground chillies. None of these adulterants are harmful. Turmeric may be detected by giving a brownish-red with ammonia, and starch by the blue colour produced with iodine, while the microscope readily detects starch grains, and cayenne pepper. The mustard seed itself contains no starch.

Pepper is largely adulterated with starch and mineral matter. Foreign starches and added mineral matter may be easily detected by the microscope.

Beverages.

It is convenient to divide beverages into two divisions, those which contain no alcohol, or the non-alcoholic beverages, and those which contain alcohol, or the alcoholic beverages.

Non-Alcoholic Beverages.

These include aerated waters, tea, coffee, and cocoa. Tea, coffee, and cocoa each possess an active stimulating principle, the effect of which is somewhat similar in each case. The stimulating principle in tea is called *theine*, and this has the same composition as the active part of coffee, called *caffeine*. In cocoa there is a similar substance called *theobromine*. The effect of these substances in moderation is to quicken and strengthen respiration and the heart's action. They also stimulate the nervous system, and lessen fatigue and the desire for sleep, for which they are valued among brain workers. Cocoa has less stimulating properties than tea or coffee, its chief value being as a food on account of the large proportion of nutritive material that it contains.

Tea, coffee, and cocoa also contain characteristic volatile oils which give to each its distinctive and peculiar smell. Tea contains, in addition, about 14 per cent. of an astringent substance called *tannin*, to which are largely due its injurious effects when taken in excess. Coffee also contains tannin, but cocoa practically none.

Tea consists of dried leaves of the tea-plant which grows in China, Japan, India, and Ceylon. Chinese teas are considered to be the best, because they contain less tannin than the other varieties. As a general rule the smaller the leaves are the better is the quality of the tea; and the trade terms pekoe, sauchong, etc., are given to the successive sizes from the same plant, each being stronger and coarser than the preceding.

The colour of the dried leaves depends upon the method of preparation. When dried over a wood fire while quite fresh they retain their green colour, but, in order to obtain a black tea, the leaves must lie in damp heaps for about 12 hours, and are then dried slowly. Black teas are to be

preferred because they usually contain more theine and less tannin.

The average dried tea-leaf contains :—

Theine	3 per cent.
Tannin	14 ,, ,,
Water	9 ,, ,,
Insoluble matter	54 ,, ,,
Ash	6 ,, ,,

It yields to the boiling water chiefly theine, tannin, and volatile oil. Theine stimulates the heart and respiration, and acts as a restorative to the nervous and muscular systems. Its great value lies in the fact that the stimulation produced by theine is **not followed by after-depression.** Tea has been found to be of great benefit to soldiers on active service, and in all cases where continuous exertion is required it is very greatly superior to alcohol as a stimulant. If prepared badly or taken in great excess it disorders digestion, and gives rise to nervousness and palpitation.

Tea should be made with boiling water, and the tea-pot previously heated so as to prevent the water being cooled. It should not be allowed to stand for more than five minutes, and at the end of this time the infusion must be poured off the leaves into another pot. If tea is brewed for a longer time it is liable to contain excessive quantities of tannin, which cause it to be bitter and astringent, and very injurious. Soft water extracts more from the leaves than hard, so that when the latter is used a pinch of bicarbonate of soda should be added to it. Tea should not be drunk too hot, and should not be taken with meat. The cup of tea before rising is undoubtedly inadvisable, and may give rise to dyspepsia. The best rule to follow is to take tea but once a day, and then only when a proper meal is taken at the same time. The Japanese powder their tea, and allow the infusion to stand only one minute. Large quantities of a preparation of this kind may be drunk without harm.

Adulterations. The extension of the tea culture in India and Ceylon, having lowered the price of tea, has rendered

adulteration less profitable and therefore less practised than formerly. The chief adulterations are the working up of used or damaged leaves to resemble fresh, the colouring or facing of the leaves, and the addition of those of other trees. The detection of used leaves, when added in reasonable quantity, is almost impossible. The most reliable information on this point is derived from the analysis of the ash of the leaves. Obviously the amount of soluble mineral matter in used tea leaves will be small, because they have been subjected to the action of boiling water. The ash of these leaves will therefore be deficient in the soluble constituents. Ordinary leaves yield about 6 per cent. of ash, and usually more than 3 per cent., *i.e.* more than half of it, is soluble in water. If the soluble part of the ash is less than half of the whole ash, it is probable that used leaves have been added.

Fig. 25.—The Tea Leaf.

To detect the presence of foreign leaves the tea should be soaked in hot water. When uncurled by hot water the tea leaf is seen to have a characteristic ovate shape and a serrated margin. The chief points to notice are (1) that the serrations of the margins cease a little before the border joins the stalk, and (2) that the apex of the leaf is notched. The arrangement of the veins is also characteristic.

The bright green tint of some teas is artificial, being produced by various pigments which may or may not be injurious. The colour of black tea is also often improved by facing, which consists in rolling the leaves with blacklead or plumbago. "Lie" tea consists of exhausted tea leaves, tea dust, and dirt of all kinds rolled up with gum and faced.

Coffee is the seed or berry of a plant growing in Arabia, Ceylon, the West Indies, and other tropical places. The

seeds are roasted until they are of a dark brown color, and then ground to powder. The chief constituents of the roasted coffee may be expressed as follows:—

Caffeine	·8	per cent.
Caffeic acids	5·0	,, ,,
Fats and oils	14·1	,, ,,
Legumin or albumin	11·5	,, ,,
Insoluble matter	48·5	,, ,,
Ash	4·6	,, ,,

The infusion contains caffeine, a little tannin, and some volatile and aromatic oils. Its action upon the body is very similar to that of tea, but is more exhilarating. It increases the frequency of the heart's action, stimulates the kidneys and the skin, and removes the sensation of fatigue. Its stimulating and invigorating qualities are valuable for men undergoing exertion in all climates: in cold climates the heat of the infusion is useful, while the increased action of the skin produces a cooling effect in hot climates. When made chiefly with milk, and sugar added, it is nutritious as well as stimulating. The stimulating effect differs from that of alcohol in not being followed by depression. Like tea, it is of great value to those engaged in laborious occupation, and for counteracting the effects of exhaustion, cold, opium poisoning, etc. In excess, it acts injuriously on the heart and nerves, and disorders digestion.

Adulteration. Chief among the adulterants is **chicory**, which is prepared from the root of the wild endive. The law allows chicory to be mixed with coffee provided that such admixture be stated. It becomes an illegal and fraudulent adulteration when it is added to samples which are sold as pure coffee. The addition of chicory is now generally taken for granted, and the amount added varies from 40 to 90 per cent. It serves to sweeten the coffee and to produce a darker coloured infusion than pure coffee gives. It is easily detected because the differences between it and coffee are well marked. These are:—

(*a*) Roasted chicory sinks in water at once and colours the water rapidly, while coffee floats for some time on

account of its oily nature. The sediment of chicory is soft and pulpy, while coffee remains hard.

(*b*) A 10 per cent infusion of chicory is much blacker than one made from coffee, and its specific gravity averages about 1024, while coffee gives a lighter infusion with a specific gravity of about 1009.

Fig. 26.—SKIN OF COFFEE.

(*c*) Under the microscope coffee presents the appearance shown in fig. 26. The portions of skin consist of long spindle cells with tapering extremities, and irregular markings, while the substance of the berry is made up of a network of fibres forming cells of irregular size and shape, containing dark angular masses and oil globules. Chicory, on the other hand, is distinguished by long ducts with ladder-like transverse markings and square extremities. The cells of chicory, moreover, are large and oval.

Roasted beans, acorns, and various starches have occasionally been used as adulterants. They are easily detected microscopically, or by adding iodine solution to the infusion, after decolourising with animal charcoal. Burnt sugar, or caramel has been added to improve the colour and taste of the infusion, and many other adulterants have been detected from time to time. Artificial berries occasionally get upon the market; they are made from a paste of starch, coloured and flavoured with a little coffee and chicory. They bear roasting and grinding well, but are reduced to a shapeless mass by steeping whole in warm water. "French coffee" usually contains from 60 to 75 per cent. of chicory, while "date coffee" and "malt coffee" consist of coffee mixed with ground date stones and malt respectively. The qualifying adjectives "French," "malt,"

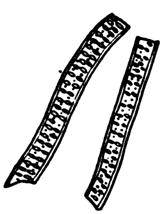


Fig. 27.—DUCT OF CHICORY.

and so on, protect the vendors from prosecution under the Sale of Foods and Drugs Act, as these are understood to denote a mixture.

Cocoa is the seed of a plant growing chiefly in the West Indies. The seeds are taken from the pod and allowed to undergo a kind of fermentation, during which the characteristic odour is said to be developed. Afterwards the seeds are roasted and deprived of their husks. They have the following composition:—

Water	3·5	per cent.
Proteids	15·5	,,
Fats	50·0	,,
Starch	13·5	,,
Theobromine	1·6	,,

Theobromine is a substance resembling theine and caffeine in composition and properties, so that cocoa resembles tea and coffee in having stimulating properties. It differs from tea and coffee by possessing a considerable amount of nutritious material. In order to disguise the excessive amount of fat it is usual to adulterate cocoa with large quantities of sugar and starch, but in the better cocoas the greater part of the fat is removed by heat and pressure. In this form cocoa may be looked upon as almost an ideal food, as it contains proteids, fats, and carbohydrates in roughly the right proportions. Prepared with milk and sugar it forms a highly nutritious and valuable stimulating beverage.

Cocoa nibs are the seeds simply broken up very roughly, while flake cocoa is the same crushed between rollers, and soluble cocoas are the same after the removal of the woody fibre. The adulterations of cocoa consist chiefly in the addition of starch and sugar, but the ground shells of the cocoa bean are sometimes added. Undoubtedly some legal limit to the addition of starch and sugar should be fixed, so that any one selling such a "prepared cocoa" as one containing 80 per cent. of starch should be liable to prosecution. No cocoa should contain less than 20 per cent. of fat.

Chocolate is finely powdered cocoa—from which the

greater part of the fat has been removed—mixed with sugar, starch, and various flavouring substances. It is particularly liable to excessive adulteration.

Mineral Waters may be divided into (*a*) the natural, derived from springs, the water of which contains gases, usually carbon dioxide, or mineral salts in solution, and (*b*) the artificial, manufactured by adding small quantities of mineral salts or some flavouring agent to ordinary water, and then aerating the solution by forcing in carbon dioxide under pressure.

(*a*) *Natural mineral waters* are generally the purest. The waters at Tunbridge, Spa, and Cheltenham are chalybeate, containing iron in the form of ferrous carbonate held in solution by excess of carbon dioxide. At Carlsbad, Vichy, Malvern, and Nieder-Seltzers are alkaline waters containing sodium carbonate and bicarbonate, and charged with carbon dioxide. Sulphuretted hydrogen impregnates the waters which are found at Harrogate and Aix-la-Chapelle. The aperient waters of Epsom and Leamington owe their action to the presence of magnesium sulphate, while those at Scarborough and Cheltenham have similar properties owing to the sodium sulphate they contain.

(*b*) *Artificial aerated waters* are essentially highly charged with carbon dioxide, and they may or may not contain alkaline salts or flavouring agents. "Soda water" does not necessarily contain any soda, and the best kinds contain the least, the amount usually added being 10 grains to the pint. The carbon dioxide contained in these beverages has a stimulant effect upon the digestive organs, and the mineral salts have a certain dietetic value. The popular prejudice against these beverages is absolutely unfounded, and is now dying away. As a result the manufacture of aerated waters has enormously increased during the past few years. Besides their effect upon the digestive organs, these liquids provide a pure beverage in those cases where the ordinary water provided is not above suspicion.

Samples of impure aerated waters are met with occasionally. These *impurities* may obtain access in several ways. (1) Impure water may be used for their manufacture. In

this case of course the aerated water would be almost as dangerous as the original supply, were it not that carbon dioxide under pressure is probably a poison to most micro-organisms. (2) The carbon dioxide may be made from impure materials. Lead, iron, copper, zinc, and arsenic have each been detected on very rare occasions in aerated waters. (3) Metallic poisons such as lead, copper and tin may be derived from the apparatus, or lead silicate may possibly be dissolved from the glass. For this reason it is advisable to prohibit the use of lead or pewter fittings to any part of the apparatus. As a matter of fact the presence of any harmful impurities in these beverages is very uncommon, except those made by inferior or faulty machines, and it is exceedingly doubtful whether any real danger to health from this source exists. Milk mixed with soda water forms an easily digested and nutritious drink, and is particularly useful to cyclists and travellers.

Fermented Drinks.

Fermented drinks may be defined as those liquids which contain the products of a process of fermentation—the most important product being alcohol. The term includes beers, wines, spirits, etc. Their common constituent is alcohol, and they also contain variable quantities of sugar, acids, salts, and aromatic oils which give to each its characteristic taste and smell.

Fermentation. If yeast is added to a solution of grape sugar, and the temperature maintained at 60°—70° F., the grape sugar is split up mainly into alcohol and carbon dioxide.

$$C_6H_{12}O_6 = 2\,C_2H_5OH + 2\,CO_2.$$

The cells of the yeast plant undergo enormous multiplication during the process, and probably the conversion of the grape sugar into alcohol and carbon dioxide is the result of this multiplication. The carbon dioxide partly escapes into the air and part remains in the liquid; the alcohol remains in the liquid. A typical fermented liquor is now obtained containing alcohol, carbon dioxide, and

probably some unchanged sugar. By subjecting this to distillation a liquid would be obtained containing practically only alcohol and water, the alcohol being present in much greater proportion than in the original fermented liquid. Alcoholic drinks may thus be divided into two kinds—(*a*) the *fermented*, and (*b*) the *distilled*. Among the former are included all beers, ales, and wines, and among the latter are the various kinds of spirits.

If cane sugar is used instead of grape sugar the yeast first of all converts the cane sugar into "invert sugar" and the fermentatation then proceeds exactly as in the case of grape sugar.

$$\underset{\text{Cane sugar.}}{C_{12}H_{22}O_{11}} + H_2O = \underbrace{C_6H_{12}O_6 + C_6H_{12}O_6}_{\text{Invert sugar.}}$$

Or, by boiling starch with dilute sulphuric acid it is converted into maltose, which ferments readily with yeast and is converted into alcohol and carbon dioxide. The legal definition of an intoxicating beverage is one that contains more than two per cent. of alcohol.

Beer should be defined as "a fermented infusion of malt flavoured with hops." A better definition of the modern beer is "the result of fermenting any sugary liquid and flavouring it with any bitter principle that has not been proved to be harmful." The preparation of beer, ale, stout, etc., which is practically the same in each case, may be divided into two stages: (1) the preparation of the sugary liquid, and (2) the fermentation process.

The preparation of the sugary liquid differs according as to whether the beer is to be made from malt or not. On this account it is customary to divide beers into two kinds: (*a*) the malt beers, and (*b*) the non-malt beers. For malt beers, the barley is soaked in a cistern for about fifty hours, and then spread out on floors for ten days or longer, during which time germination takes place, and the grain sprouts. If tasted now the grain will be found to be sweet. This is because the ferment called diastase has been formed in the grain, and this has the power of converting starch into sugar. This diastase is the active

part of "**malted foods**," and the value of these foods lies in the fact that diastase has the power to convert starch into sugar. They are useful for weakly children and for invalids.

When the germination has proceeded far enough, all further action is stopped by drying the grain over a kiln. It is now called **malt**, and is passed on to the brewer who, after crushing it, heats it with water up to about 160°F. This process completes the conversion of the starch into sugar by the diastase, and this is dissolved in the hot water, forming a sugary liquid called **wort**. The wort is then boiled with hops, a process which imparts the bitter flavour to the beer, and at the same time clears the wort by coagulating any albuminous matter that may have been dissolved from the malt.

For non-malt beers the sugary liquid is prepared by converting starch or cane sugar into grape sugar or invert sugar in the way described above.

For the fermentation process, the wort is run into shallow vessels, where it is cooled down to the desired temperature. The necessary temperature varies according to the kind of yeast which is to be used for the fermentation. The English yeast, which floats on the top and is therefore called "top" yeast, works best at a temperature of about 65°F., but for "bottom" or sedimentary yeast, which sinks to the bottom, and is used in Germany, a temperature about 55°F. is preferable. When cooled to the necessary temperature the liquid is run off into the fermenting vat, yeast is added, and the fermentation allowed to proceed for about a week. During this time some of the sugar is converted into alcohol and carbon dioxide, but some sugar remains unaltered.

The practical points to be noted in connection with brewing are: (1) that yeast works better when transferred from one kind of beer to another; (2) that the amount of yeast required and the most advantageous temperature vary with the different kinds of beer; and (3) that the fermentation must not be allowed to proceed so far as to convert the whole of the sugar into alcohol, otherwise the beer will not keep well.

The *composition* of beer may be expressed as—

Water, about 90 per cent.
Alcohol, 3—8 per cent.
Malt extract (dextrin, sugar, etc.), 5—10 per cent.
Carbon dioxide, Salts, Albuminous matters, Acids—acetic and lactic: in small quantities.

The variation in the amount of alcohol is considerable. As a rule the German beers contain less alcohol than the English, especially the Bavarian beer, which contains only 2 per cent. German beers are also less bitter, keep better, and contain more carbon dioxide than ours. The lager beers are the strongest.

Bavarian	beer,	2	per cent.	alcohol.
Prague	,,	2½	,,	,,
Lager	,,	5	,,	,,
Porter,		5	,,	,,
Burton	ale,	6	,,	,,
Edinburgh	,,	8	,,	,,
Berlin	,,	7½	,,	,,

The variations in the colour of beers and ales are produced by the different degrees of charring to which the malt has been subjected. The density and dark colour of stout and the heavier porters is obtained by the addition of treacle, linseed, liquorice, or sugar burned to different degrees of blackness.

Attention has recently been called to the presence of arsenic in beer. The chief source of this is undoubtedly the use of impure sulphuric acid in the conversion of starch into glucose, or cane sugar into invert sugar. If beer is made from malt and hops only, there is practically no possibility of any appreciable quantity of arsenic getting into the beer.

The nutritive value of beer, ale, stout, and porter, although higher than that of any other alcoholic drink, is extremely small, being practically the same as a very weak solution of sugar in water. The drowsiness produced by

these drinks is probably due to the oil of hops. The general effects are, of course, those produced by varying doses of alcohol, but, at the same time, beer seems to produce effects peculiar to itself. If taken in excess it leads to the storage of superfluous fat in the tissues, and interferes with the proper elimination of waste matters. Eventually an excessive amount of uric acid is formed and plethora and gout are produced.

Adulterations of Beer. In Bavaria the substitution of glucose, invert sugar, or other sugars for malt is absolutely prohibited, the only bitter principle that is allowed is hops; and burnt malt is the only colouring agent that is permitted. In this country, however, there are no such prohibitions, and unlimited amounts of artificially prepared sugars are substituted for malt; hops are replaced by gentian, quassia, calumba, and other bitters; and the desired colour is obtained by the addition of burnt sugar. Caramel, treacle, and liquorice are added to thicken and darken the complicated mixtures called stout and porter. Salt and alum are commonly added, both with a view to excite thirst and to increase the density after dilution of the beer with water. Sugar is also occasionally added to restore the density and to give the beer a "head." Such beers are liable to undergo secondary fermentation and become sour and unwholesome. The amount of common salt should not exceed 20 grains per gallon. Other possible adulterations include salicylic acid which is added to prevent secondary fermentation, and sodium bicarbonate to increase the effervescing property of the liquid.

The different preparations of beer may be represented by the following :—

BARLEY	STARCH boiled with dilute sulphuric acid	CANE SUGAR boiled with dilute sulphuric acid
MALT (Starch + Diastase)		
GRAPE SUGAR which is fermentable by yeast.	GLUCOSE which is fermentable by yeast.	INVERT SUGAR which is fermentable by yeast.

Beer.

Wine should be defined as the fermented juice of the grape. In this case the fermentation is not set up by adding yeast to the liquid, but begins spontaneously from the germs present in the air or adhering to the skins of the grapes. Red wines owe their colour to the colouring matter obtained from the skins of the dark grapes, and their astringency is due to the fact that the seeds, which contain tannin, are left in the liquid during fermentation. There are usually present in wine variable quantities of water, alcohol, carbon dioxide, ethers, colouring matter, vegetable acids, tannin, salts, and sugar. Lighter wines —the Bordeaux, Burgundies, Rhine wines, Moselles, and Champagnes—usually contain about 10 per cent. of alcohol by volume, while the stronger ones, port, sherry, and Madeira contain from 15 to 25 per cent. It has been conclusively proved that the fermentation of any sugary liquid stops when the alcohol reaches 14 per cent., so that it is obvious that any alcohol above 14 per cent. must have been added to the wine subsequently—a process which is known as "fortifying" the wine.

Wines vary also in the amount of sugar they contain. In some cases the whole of the sugar has been converted into alcohol, and the result is a "dry" wine. On the other hand, in other cases, a considerable quantity of sugar remains unconverted, giving a sweet wine. The acidity of wine is due to the presence of free acids, *e.g.* acetic, malic, and tartaric acids, and acid salts such as cream of tartar, which is acid potassium tartrate. It is usual to express the acidity in terms of tartaric acid, which should not amount to more than 1·2 per cent.

It is possible to make true wines from other fruits than the grape, the gooseberry, currants, apples for instance, but the so-called "British wines," sold under the name of orange wine, ginger wine, etc., are usually simply diluted spirit flavoured and sweetened. Moreover, the real wines are subjected to so many trade processes that when they reach the consumer they bear but small resemblance to the original article. "Fortifying" has been already mentioned. Another process called "plastering" consists in the addition of calcium sulphate which is added to precipitate the

albumin and hasten the clearing of the liquid. This process is liable to be injurious to health, so that in France the quantity of sulphates is not allowed to exceed ·2 per cent.

The substances employed for the **adulteration of wine** are mostly added during the processes of fortifying and colouring. Ports, champagnes, and sherries are always fortified with brandy, ports are coloured with elder-berries, and sugar is added to the sweeter varieties such as champagne. Other adulterants include water, various ethers, logwood, sulphate of lime, and alum. Reference has been already made to the addition of sulphate of lime, or plastering. It clears the wine, and makes it look brilliant. The chemical result is the partial substitution of sulphates and sulphuric acid for tartrates and tartaric acid, a result that renders the wine distinctly injurious. Sherries are most liable to this form of adulteration. Ports and sherries are largely made from potato spirit and cider, while champagnes often contain no grape juice whatever, being manufactured from rhubarb, apples, and other fruits.

The nutritive value of wine is extremely small, and is due solely to the variable quantity of sugar that it contains Its effects are due to the alcohol that is present. Port and sherry predispose to gout, and should never be indulged in by any who have inherited tendencies to this disease.

Spirits are obtained by distilling various fermented liquids. All contain alcohol as their essential ingredient, together with varying quantities of water, fusel oil and aromatic bodies which give to each its characteristic taste and smell. In every case distilled spirits are colourless when first made, the distinguishing tints being purely conventional, and produced by the addition of more or less burnt sugar.

Brandy was originally manufactured by the distillation of wine, and is still so prepared in some parts of France, where it is sold as Cognac. The greater part of the brandy in the market is obtained by distilling fermented malt or potatoes. It contains from 45 to 60 per cent. of alcohol.

Whisky is prepared by distilling a fermented infusion

of malted grain. The inferior varieties are obtained from oats, barley, rye, or potatoes, roughly distilled and burnt in order to give it the desired smoky flavour. It contains about the same amount of alcohol as brandy.

Rum is the distillate from fermented molasses. Like brandy, it is artifically coloured with burnt sugar. It usually contains between 50 and 60 per cent. of alcohol.

Gin is usually obtained by the distillation of fermented infusions of malt and barley, with the addition of oil of juniper, orange peel, oil of turpentine, and other aromatic substances. The juniper and turpentine act as direct stimulants of the kidneys.

Proof Spirit. This term arose from the old way of pouring the spirit over gunpowder, and setting fire to the liquid. If the spirit burned without igniting the powder it was "under proof," and the weakest spirit that was capable of firing the powder was called "proof spirit." The term "proof spirit" as now used implies a solution of alcohol in water, containing 57·05 per cent., by volume, of absolute alcohol. Its specific gravity at 60° F. is 919·8. Stronger solutions than this are "over proof," and weaker solutions are "under proof." Thus, a sample of spirit is said to be 10 degrees over proof when 100 parts of it contain as much alcohol as 110 parts of proof spirit; while it would be 10 degrees under proof if 100 parts of it contain as much alcohol as 90 parts of proof spirit. Brandy, whisky, and rum are allowed to be as many as 25 degrees under proof, the percentage of absolute alcohol in this case being 42·8. Gin may be 35 degrees under proof, and contain only 37·1 per cent. of absolute alcohol.

Effects of Alcohol. When alcohol is swallowed, it passes unchanged through the lining membrane of the stomach and reaches the blood. The following effects are then produced:—(1) The vessels of the stomach are dilated, and the flow of gastric juice is augmented for a time. (2) The force and frequency of the heart are increased. Respiration is similarly affected; in fact, all the organs of the body may be said to be stimulated by alcohol. (3) The nerves to the blood vessels in the skin are paralysed, causing the vessels to dilate and producing the flushing of

the skin. This gives the sensation of warmth and is the basis of the old tradition that alcohol warms the body and therefore should be taken when the body is about to be exposed to severe cold. This is a most dangerous fallacy, and has undoubtedly been the cause of many deaths from exposure. (4) As a matter of fact, alcohol actually *lowers* the temperature of the body, an effect which is caused to some extent by the dilation of the blood vessels just beneath the skin, which increases the loss of heat. (5) The brain is partly anaesthetised; the rapidity of external impressions, the discrimination of the senses, and the power of concentrated thought are lessened. The capacity for sustained muscular exertion is also decreased. (6) The amount of water and the acidity of the urine are somewhat increased.

Taken in excess, alcohol speedily passes out of the body in an unaltered condition, chiefly by the lungs and the breath, but also in small quantities by the skin, the urine, and the bowels. In small quantities alcohol probably becomes oxidised by the body, leading to the production of a small amount of heat and energy. The long-continued immoderate use of alcohol leads to degenerative changes, particularly in the stomach and liver, and also, at a later period, in the blood-vessels, the kidneys, lungs, and brain, thereby increasing the tendency to gout, Bright's disease, and insanity. Its effect in shortening life is now universally recognised, and the evidence of statistics on this point is overwhelming. As a rule the rate of mortality among the intemperate may be stated to be between four and five times greater than that of the strictly temperate of the same age and in the same class of life.

There can be no doubt whatever that a person can do quite as hard or harder work without alcohol as with it. It is a matter of experience that soldiers on the march, in all climates, can endure more fatigue, are healthier, and fight better without alcoholic stimulants than with them. The infinite amount of suffering caused by alcohol is a matter of common knowledge. About three-quarters of the people in workhouses are there, directly or indirectly, owing to alcohol; at least half the crime in

the country is caused by it, and about one-third of the insanity.

For all practical purposes alcohol is valueless as a food. Its value, when used by a scientific medical man, depends upon its physiological effects. In strictly moderate doses, however, alcohol does not produce any immediate obvious ill-effect, and is claimed by some to aid digestion and assimilation. By a moderate dose is meant between one and one-and-a-half ounces of pure alcohol a day. This amount of alcohol is contained in about one pint of beer, less than half-a-pint of claret, or three ounces of spirit.

The recent international manifesto issued jointly by the British Medical Temperance Association, the American Medical Temperance Association, and the Association of German-speaking Medical Men, presents the case against alcohol in a clear and concise fashion. As these associations are composed solely of medical men, the views embodied in the manifesto should produce a greater effect upon the public than the mere opinion of unqualified persons. The document declares that in view of the terrible evils that have resulted from the consumption of alcohol, evils which in many parts of the world are rapidly increasing, the signatories feel it to be their duty to speak plainly of the nature of alcohol, and of the injury to the individual and the danger to the community which arises from the prevalent use of intoxicating liquors as beverages. They think it ought to be known by all that:—

1. Experiments have demonstrated that even a small quantity of alcohol, either immediately or after a short time, prevents perfect mental action and interferes with the functions of the cells and tissues of the body, impairing self-control by producing progressive paralysis of the judgment of the will; and having other markedly injurious effects. Hence alcohol must be regarded as a poison, and ought not to be classed among foods.

2. Observation establishes the fact that a moderate use of alcoholic liquors, continued over a number of years, produces a gradual deterioration of the tissues of the body and hastens the changes which old age brings, thus

increasing the average liability to disease (especially to infectious disease), and shortening the duration of life.

3. Total abstainers, other conditions being similar, can perform more work, possess greater powers of endurance, have on the average less sickness, and recover more quickly than non-abstainers, especially from infectious disease, whilst they altogether escape diseases specially caused by alcohol.

4. All the bodily functions of man, as of every other animal, are best performed in the absence of alcohol, and any supposed experience to the contrary is founded on delusion, a result of the action of alcohol on the nerve centres.

5. Further, alcohol tends to produce in the offspring of drinkers an unstable nervous system, lowering them mentally, morally, and physically. Thus deterioration of the race threatens us, and this is likely to be greatly accelerated by the alarming increase of drinking among women, who have hitherto been little addicted to this vice. Since the mothers of the coming generation are thus involved, the importance and danger of this increase cannot be exaggerated.

In conclusion, the manifesto states that, as the common use of alcoholic beverages is always and everywhere followed, sooner or later, by moral, physical, and social results of a most serious and threatening character, and that it is the cause, direct or indirect, of a very large proportion of the poverty, suffering, vice, crime, lunacy, disease, and death, not only in the case of those who take such beverages but in the case of others who are unavoidably associated with them, the signatories feel compelled to urge the general adoption of total abstinence from all intoxicating liquors as beverages, as the surest, simplest, and quickest methods of removing the evils which necessarily result from their use.

PRACTICAL WORK ON CHAPTER IV.

I. VINEGAR.

1. Pour some wine or beer into a beaker and leave it exposed to the air for a few days. The liquid gradually develops a sour taste and will turn blue litmus paper red, showing that an **acid** has been produced.

2. Obtain some **vinegar**, note its colour, taste, and smell. Test its reaction with litmus paper.

3. **To estimate the acidity of vinegar.** Take 25 c.c. of vinegar, dilute it with distilled water until its volume is exactly 250 c.c. Take 25 c.c. of this liquid, add a few drops of phenolphthalein as an indicator, and run in a decinormal solution of soda, *i.e.* a solution containing 4 grammes of caustic soda per litre, until the last drop produces the characteristic colour with the plenolphthalein. The number of c.c. of soda required $\times$ ·006 $\times$ 100 = percentage of acetic acid in the vinegar.

4. **To test for sulphuric acid in vinegar.** To a small quantity of vinegar in a test tube add a few drops of nitric acid and then some solution of barium chloride. If a precipitate is produced, the presence of sulphuric acid is shown.

II. MUSTARD.

1. **Test for turmeric** by adding a little ammonium hydrate solution to some mustard. If the yellow colour changes to a brownish-red the presence of turmeric is proved.

2. Mix a little mustard with water, and then add several times its bulk of boiling water. Then add one drop of solution of iodine. A blue colour shows the **presence of starch.**

III. PEPPER.

Pour a small quantity of pepper into a dry test tube and then add sufficient strong hydrochloric acid to cover it well. If the sample is **pure pepper** it acquires an intense yellow colour, and most of the adulterations can easily be detected by remaining uncoloured.

IV. TEA.

1. **Examine the leaves.** Pour some hot water over one or two of the larger leaves. They should uncurl quickly when thus treated. Now spread them out between glass slides and hold them up to the light. The characteristics of the leaves should agree with those described on p. 93.

2. **To test for tannin.** To some strong tea in a test tube add a few drops of ferric chloride solution. An inky liquid is formed showing the presence of tannin.

3. **To estimate the tannin.** Weigh out 2 grammes of the powdered tea into a small dry flask; cover with 100 c.c. distilled water, and boil for 1 hour. Filter while hot. Pour over the residue another 100 c.c.

of boiling water and filter this through the same paper. Receive both filtrates in the same beaker. To the clear liquid add a solution of gelatin until no more precipitate is produced. Filter the liquid through a weighed filter paper, dry the precipitate in an oven at about 120° C., and weigh when quite dry. The tannin may be taken to be 40 per cent. of the dried precipitate. Calculate the percentage of tannin in the sample of the tea taken. (This method gives only an approximate result.)

4. **To estimate the ash.** Take 10 grammes of tea, place in a weighed dry porcelain or platinum dish, and gently heat with the Bunsen flame until it is reduced to an ash, which is generally grey or greenish in colour. Cool and weigh again. Calculate the percentage of ash in tea. It should be between 4 and 6 per cent. In faced teas the ash may be 10 per cent., while in "lie tea" it may reach 30 per cent.

Partly fill the dish with boiling water, stir with glass rod and pour into a filter. Wash out the dish with more boiling water, passing each washing through the filter. The hot water dissolves the soluble part of the ash, while the insoluble part remains on the filter paper. Place the filter paper and its contents in a weighed platinum crucible and heat until the contents are reduced to a fine ash again; cool and weigh again. Calculate the percentages of insoluble and soluble ash in tea. The soluble part of the ash should amount to half the total ash.

5. **The action of tannin on proteids.** Make a solution of tannin in hot water. Then dissolve some isinglass in boiling water. Add the tannin solution to the isinglass. A white precipitate is produced. This experiment illustrates the action of strong tea on any proteids, such as meat.

V. Coffee.

1. Test a sample of coffee for **chicory** by the methods given on pages 94 and 95.

2. Determine the percentage of **ash** as in (4) above.

VI. Cocoa.

1. Examine by the microscope for the starch granules of **added starch.**

VII. Fermented Drinks.

1. Fit up the apparatus shown in fig. 28. Put in the flask sugar and water, and add some brewer's yeast. Leave it in a warm place for some hours. A clear colourless gas collects in the jar. Add some lime water and shake it up. The lime water is turned milky, showing the gas to be **carbon dioxide.**

2. Filter the contents of the flask, and pour the clear liquid into a retort, fitted with a condenser as in fig. 29. Note the smell of the liquid that distils over. When about a teaspoonful of the liquid has collected in the cooled receiver, pour it into a watch glass and apply a

light. The liquid burns with a pale flame, showing that **alcohol has** been formed.

3. Repeat experiment (2) using **beer** or **wine** for the distillation.

4. Place a very minute fragment of yeast upon a microscope slide. Add one drop of water and mix the yeast with it by means of a platinum wire. Spread the mixture evenly over the slide, cover with

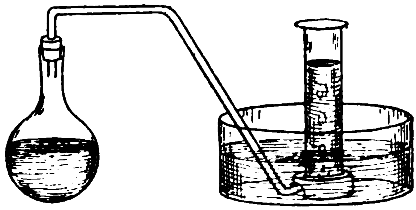


Fig. 28.—FLASK FOR FERMENTATION.

a coverglass and examine it under the microscope. The yeast is seen to be composed of tiny oval bodies, each of which is a **living plant,** and is capable of multiplying and bringing about the conversion of sugar into alcohol and carbon dioxide.

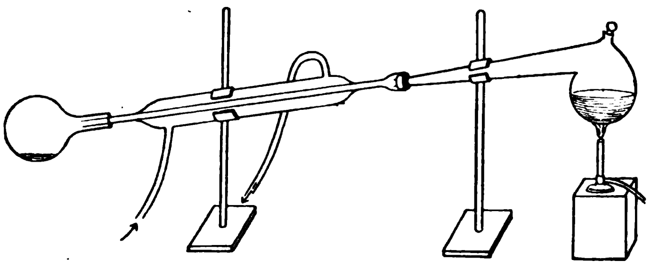


Fig. 29.—DISTILLATION APPARATUS.

5. **Determine the boiling point of alcohol.** To do this pour an ounce of alcohol into a Wurtz flask fitted with a condenser and having a thermometer passing through the cork so that the bulb of the thermometer is just above the surface of the alcohol. Gently heat the alcohol until it boils. The mercury in the thermometer rises up to about 78°C. and then remains stationary. The alcohol vaporised by the heat is liquified in the condenser and so none is wasted.

6. **To estimate the amount of alcohol in a given liquid.** About a pint of beer should be either well shaken in a large bottle and allowed to stand, or rapidly poured, "tossed," from one vessel to another. This is to expel as much of the CO_2 as possible. Place 250 cc. in a retort connected with a condenser and receiver, make alkaline with caustic soda solution, aud boil gently until two-thirds of the liquid has passed over into the receiver. Then pour the distillate into a 250 c.c. flask, and add distilled water until the level of the liquid stands at the mark. Next find the density of the liquid by weighing a measured volume of it, preferably in a specific gravity bottle. Calculate the weight of 1000 c.c. of the liquid. If this weight is 1000 grammes then the beer would be free from alcohol, and the more the weight is below 1000 grammes the greater is the amount of alcohol in the beer because 1000 c.c. of alcohol weighs only 793·8 grammes. It is assumed that the whole of the alcohol in the beer has passed over when two-thirds of the liquid has distilled. Calculate the percentage of alcohol in the beer by means of the following table.

Weight of 1000 c.c.	Per cent. of Alcohol.
1000	0
997·6	1
996·1	2
994·7	3
993·3	4
991·9	5
990·6	6
989·3	7
988·1	8
986·9	9
985·7	10

7. **The acidity of beer.** This is an important determination. Measure 100 c.c. of beer into a 250 c.c. flask and fill up to the mark with distilled water. Take 25 c.c. of this diluted beer, add phenolphthalein as an indicator and run in decinormal soda solution until the liquid is neutral. Not more than 3 c.c. of the decinormal soda solution should be required. The normal acidity of beer depends upon carbonic, acetic, lactic, tannic, and malic acids, but it is occasionally increased by the addition of sulphuric acid.

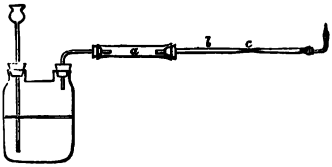


Fig. 29A.

8. **Detection of arsenic in beer.** Fix up the apparatus shown in fig. 29 A. The tube (*a*) is filled with fragments of calcium chloride to dry the gas. Put into the bottle some pure zinc and pure dilute hydrochloric acid. When all the air has been expelled and the hydrogen is freely coming off light it at the jet and heat the constricted part of the tube (*c*). There should be no deposit on the tube at the heated part. Then pour into the flask some of the beer to be tested and some more pure hydrochloric acid. Continue heating the constricted part of the tube. If arsenic is present in the beer a stain will be produced on the hot tube. This is arsenic, and it may be distinguished from other similar stains by its solubility in a solution of sodium hypochlorite.

CHAPTER V.

PERSONAL HYGIENE—EXERCISE—HABITS.

THE judicious combination of exercise, rest, and sleep plays a very important part in the health of the individual. Lack of exercise is soon followed by atrophy, or wasting away of the parts that are not used. A muscle that is not exercised, but lies idle, soon wastes away and becomes useless. This is particularly noticeable in the case of a broken or paralysed limb. The lack of use soon produces wasting and loss of power of the limb. The brain also, when not exercised by study and reading, does not develop to its fullest possible extent. On the other hand, unless the exercise is combined with the proper amount of rest, the results are even more disastrous, as the body becomes overworked and exhausted.

Exercise is necessary at all periods of life, but especially so during childhood and early manhood or womanhood. It is the duty of all parents to see that their children enter into the school games, and spend a great deal of time in the open air. Practically all schools have now adopted physical exercises as part of their curriculum in recognition of the importance of these to the children. In the case of adults the exercise that should be indulged in must depend upon the nature of the daily work. Thus, if a man is doing bodily work all day, his muscles have had quite sufficient exercise, and mental exercise is what he needs for his spare time. On the other hand, those whose occupation is sedentary, such as clerks, students, etc., need physical exercise in their spare time, in order to bring their muscular, circulatory, and respiratory systems to the proper pitch of development.

For any beneficial result, the exercise taken must be systematic and regular, and not indulged in by fits and starts. By gradually and steadily increasing the work done by them, a set of muscles may be greatly increased in size, but there is a limit to this increase, and if the work be carried to excess the muscles will begin to waste away. Care should be taken to give every muscle of the body its necessary exercise. Many of our sports are faulty in leaving most of the muscles idle. The best real exercise for all the muscles is probably obtained by boxing, lawn tennis, and Rugby football.

Violent exercise should never be taken without proper training. By training, we do not mean the old-fashioned idea of feeding a man on limited rations of half-raw meat, but simply an outdoor life, with plenty of good, nourishing food, and no lack of exercise for all the muscles. Violent exercise, without proper training of this kind, is likely to lead to most disastrous results, the commonest of which is heart disease resulting from overstrain.

Some of the physiological effects of exercise deserve special mention. We have already mentioned that the muscles are increased in size and are rendered capable of doing more work. By exercise they are also brought more under the control of the will. The first effect of exercise is, perhaps, the quickening of the heart beat and the rate of respiration. The **heart** beats more rapidly and more forcibly, causing an increased flow of blood through the blood vessels all over the body. If the exercise be sudden and violent, the heart may be incapable of meeting this sudden demand upon it, and the valves may be rendered incompetent, giving rise to heart disease. But by gradually increasing the exercise, the heart is strengthened and the coats of the arteries are made stronger and healthier.

Respiration is also quickened by exercise. The amount of air taken in at each inspiration is increased, and larger quantities of water and carbon dioxide are given out in the expired air. Thus, a man at rest draws into his lungs each minute about 480 cubic inches of air, but if walking at the rate of three miles per hour he takes in 1550 cubic

inches of air, and if he increases his rate to six miles per hour, the amount of air that he inspires is raised to 3250 cubic inches.

The **skin** acts freely while exercise is being taken. The blood vessels surrounding the sweat glands are distended with blood, and the secretion of sweat is increased. In this way an extra quantity of waste matter is removed from the body by the skin.

Other effects of exercise include the exhilaration and strengthening of the **nervous system**, the improvement of the appetite and **digestion**, and the stimulation of the **kidneys** and **bowels**, thereby aiding the elimination of waste matters from the body.

Rest. Without proper rest the organs of the body would soon become worn out. The most absolute rest is that obtained by **sleep**. The amount of sleep required varies with the age and occupation, but, speaking generally, the average adult requires 7 or 8 hours sleep a day. Children require more sleep than adults because their bodies are working at a greater rate, and they are more easily exhausted: those under 4 years should have 16 hours sleep a day; from 4 to 12 years of age they require 12 hours sleep; from 12 to 16, 10 hours sleep is necessary.

The sleeping-room should be quiet and well ventilated. Bedsteads should always be used, if possible, as sleeping upon the floor is less healthy on account of the interference with the free circulation of air around and under the sleeper, and also the increased liability to inhale dust or gases from the floor. A hair mattress is very much to be preferred to a feather bed. Infants should not sleep with adults, as the risk of "overlaying" is very great under these circumstances. They should always sleep in a separate bed or cot, which may be easily constructed out of an ordinary clothes'-basket or box.

Habits. Either good or bad habits are bound to be formed by children as they grow up, and so it behoves all good parents to see that the habits that the children form are those which are conducive to their health and happiness. The habit of eating slowly and chewing the food

well, and of having regular meals has already been referred to. The danger of forming the habit of taking alcoholic drinks has also been mentioned. Among the necessary and important habits are cleanliness, proper attention to the teeth, and the regular action of the bowels.

The teeth should be cleaned regularly once or twice a day. If cleaned only once a day the best time is night, just before retiring to rest. A good tooth powder is a mixture of equal parts of salt and carbonate of soda. When any signs of decay of the teeth appear they should be stopped by a dentist. The teeth of children should be systematically examined for traces of decay or signs of irregularity. Irregularity can often be corrected to some extent by a skilful dentist.

The bowels should be freely opened at least once a day. The best way to secure this is to cultivate the habit of evacuating the bowels at the same time each day. If a regular habit is not formed, constipation is bound to occur, and this will produce indigestion, hæmorrhoids or piles, and sometimes inflammation of the bowels. Aperients should rarely be needed. A far better way to procure proper action of the bowels is to take regular exercise, and eat brown bread, oatmeal, vegetables, and fruit.

Causes of Disease.

The causes of disease are usually divided into two groups, viz.:—(*a*) predisposing, and (*b*) determining. (*a*) Predisposing causes are certain conditions of the body, *e.g.* temperament, idiosyncrasy and constitution, which increase its liability to disease. (*b*) Determining causes are those which actually produce the disease. "Thus, if a big man stands up to be shot at in a duel, he is more likely to be hit, other things being equal, than a small one; and so his size is a predisposing cause in favour of his being killed. If he is killed, it is the bullet which is the determining cause" (Corfield). Similarly with such a disease as consumption, occupation, lack of sufficient air space, and heredity may be said to be predisposing causes, but the determining cause is the invasion of the lungs by the

tubercle bacillus. Among the chief predisposing causes may be mentioned the following:—

1. **Constitution.** An individual is said to possess a strong constitution when his or her body is in such a condition as to be able to resist the attacks of disease. A weak constitution on the other hand denotes a condition of the body which renders it always liable to be invaded by disease, and when thus attacked, less able to offer a successful resistance. By careful temperate habits it is possible, however, for a person with a comparatively weak constitution to live longer and remain healthier than one who presumes upon a strong constitution by indulging in bad habits.

Temperament—a term introduced by the ancient physicians—is closely connected with constitution. It is usual to speak of three temperaments—the sanguine, the nervous, and the lymphatic. A **sanguine** temperament is possessed by people with robust and strong constitutions, great animal spirits, and a good circulatory and respiratory system. Such people are rarely ill, and when attacked by disease they rapidly recover. A **nervous** temperament involves a predisposition to nervous diseases, and is by no means a healthy condition. People with such a temperament should indulge in outdoor exercise, or take up some occupation which enables them to spend most of their time in the open air; and a large allowance for rest and sleep should be made. A **lymphatic** or **phlegmatic** temperament is possessed by listless and inactive people. Children of this type should be encouraged to play or work in the open air, and, as they are particularly liable to be attacked by scrofula and consumption, should live in well-ventilated rooms and be supplied with nourishing fatty food.

2. **Heredity.** Every-day experience shows that not only are external resemblances handed down from parents to their children, but mental and moral characteristics, as well as tendencies towards certain kinds of disease, are also frequently hereditary. It is important to remember that it is the tendency towards a disease and not the disease itself that is inherited. Thus, the children of consumptive

parents will probably inherit a constitution which is particularly liable to succumb to attacks of the tubercle bacillus. It behoves such people to take special precautions to overcome the inherited weakness by :—(*a*) taking plenty of exercise in the fresh air, (*b*) living in dry, well-ventilated rooms, and (*c*) eating a plain wholesome diet containing a large proportion of fats. Another example of hereditary tendency is a certain imperfection or weakness in the digestive apparatus which results in gout. To combat this the greatest care in diet should be taken, and plenty of outdoor exercise. Rheumatism, chorea (St. Vitus's dance), and heart disease often attack members of the same family, while examples of the hereditary tendencies of epilepsy and insanity are unfortunately only too common. The children of persons suffering from nervous diseases should be encouraged to indulge far more in physical exercise than in study, especially in their earlier years. Scrofula and cancer are further examples of diseases which appear to attack persons with an inherited tendency.

The tendency to any disease is greatly increased by the inter-marriage of families with the same hereditary taint. Thus, if members of two tubercular families were to marry, their children would be particularly liable to develop consumption; and similarly with most of the above diseases. For this reason it is inadvisable for relations to marry because they may both have inherited a family taint which will be intensified in their offspring.

3. **Idiosyncrasies** are peculiarities or weak points in a constitution to which special attention should be paid in order to ward off those diseases which are most likely to attack it. It is often noticeable that the same cause will produce very different effects in different people. "Thus, if a regiment of men encamp on marshy ground, one man may get a sore throat, another a cold in the head, another bronchitis, another rheumatic fever, another rheumatism, another intermittent fever or ague, and another nothing at all; the reason of all this being that each man was attacked in his weakest point" (Corfield). Similar examples are afforded by the different effects of some foods and drugs. Shell-fish, for instance, may produce serious poisoning in

some people while they may be consumed with impunity by others. The action of opium and morphia is found to vary with the individual. With regard to diseases certain people seem to possess remarkable idiosyncrasies towards some complaints, being attacked two or even three times by such a disease as small-pox, or typhoid fever, one attack of which, as a rule, confers immunity from that disease for the rest of life.

4. **Age.** An examination of statistics show that the age of an individual plays an important part as a predisposing cause of disease.

In infancy the dangers arise chiefly from (*a*) improper clothing, (*b*) improper feeding, and (*c*) communicable diseases.

A child needs to be warmly clad because it loses its heat more rapidly than an adult, owing to the fact that its external surface is greater in proportion to its size than an adult's. In winter, therefore, if children are not warmly clad, they are likely to be attacked by bronchitis, which proves fatal in many cases. As regards food, the child should be fed entirely upon milk until the age of nine months is reached, and even then starchy foods should be given in great moderation. If improperly fed, children are liable to attacks of vomiting, convulsions, and diarrhoea, the latter being a particularly fatal disorder. Rickets also may occur in children who are fed too early upon starchy foods, especially if, at the same time, their surroundings are unhygienic. The communicable diseases—small-pox, measles, scarlet fever, whooping-cough, chicken-pox, and diphtheria—are very prevalent in infancy, and are generally much more fatal then than if taken later on in life. It is of the utmost importance, therefore, to prevent any possible infection from cases suffering from these complaints. That terrible disease, small-pox, has been transferred from among the diseases of infancy to that of young adults by means of compulsory vaccination, but this will only be maintained if the vaccination of all infants is insisted upon. If the number of unvaccinated infants in our population reaches an appreciable proportion of the whole, small-pox will probably resume its previous position as the

most fatal and most terrible of the diseases of infancy and childhood. It is obviously important to point out that a child need not **necessarily** be attacked by any communicable disease at all, and that each year of life, in most cases, decreases the probability of its acquiring any of them. Rheumatic fever is common in childhood, the after effects of which, in the form of heart disease, are often most disastrous. A great number of deaths among children are brought about by accidents, such as "overlaying."

Youth. If vaccination has been performed in infancy its effects as a preventive of small-pox will last until the thirteenth or fifteenth year, when re-vaccination should be performed. This precaution is often neglected, and the effect is that small-pox is prevalent at this time of life. If re-vaccination were made compulsory at the age of twelve it is extremely probable that this disease would be rapidly stamped out altogether.

Rheumatic fever—which often results from carelessness in wearing wet clothes—and consumption are most prevalent and fatal at this period of life. The latter disease is commonest among those who are the victims of overcrowding, and the inhabitants of badly ventilated rooms, especially if they are predisposed to it by a hereditary tendency. Similar causes also tend to produce blood disorders which are classed together under the name anaemia. Among the communicable diseases the most important in youth is enteric or typhoid fever.

Adults. Communicable diseases are comparatively rare, and the chief dangers are due to the chronic diseases, *e.g.* bronchitis, heart diseases, and diseases of the liver and kidneys. The tendency towards gout, cancer, and nervous disorders increases towards the latter part of this period of life. Some of these complaints are, to some extent at least, avoidable, *e.g.* diseases of the liver and kidneys are often caused by alcohol, and chronic bronchitis is usually the sequence of a series of neglected colds.

Old Age. The chief causes of death in old age are bronchitis, cancer, paralysis, and apoplexy, the last being often the result of kidney disease.

5. **Sex**. As a general rule it may be said that at every age men die at a greater rate than women. For instance, in 1891 the death rates in England and Wales were :—

	Deaths per 1000 persons living.	
	Males.	Females.
Under 5 years	62·1	52
Between 5—10 ,,	4·5	4·5
,, 10—15 ,,	2·5	2·7
,, 15—20 ,,	4·0	4·0
,, 20—25 ,,	5·3	4·5
,, 25—35 ,,	7·2	6·7
,, 35—45 ,,	12·2	10·3
,, 45—55 ,,	19·8	15·3
,, 55—65 ,,	36·3	29·8

As this extra mortality among men begins at such early ages it cannot be due to occupation and exposure entirely, and there appears to be some predisposing cause. Many diseases are found to kill more males than females, especially : (1) kidney diseases, which are often caused by excessive consumption of meat and alcohol, (2) lung diseases, generally due to exposure, (3) brain diseases, which are often brought about by great worry and anxiety, and (4) some communicable diseases, such as small-pox, measles, and scarlet fever. Accidental deaths and suicides are also more common among males than females. On the other hand, it is generally found that such diseases as cancer, diphtheria, whooping cough, typhoid, and typhus fever are more liable to attack women than men. The death rate due to consumption among people under 20 years of age shows more female victims than male, but over 45 years the reverse is the case, so that the total death rate due to consumption is about the same.

Clothing.

The chief **uses of clothing** are :—

1. *To keep in the heat of the body.* The heat produced by the metabolism of food, *i.e.* chemical changes of food when in the body—would, but for our

clothing, pass from the surface to the external air, because the temperature of the body is nearly always higher than that of the air surrounding it.

2. *To protect the body from being injured by excessive heat* in tropical districts. Light-coloured clothing is worn to reflect the heat.
3. *To protect the body from wind and rain.*
4. *To protect the body from injury* arising from contact with external objects.
5. *To adorn the body.*

The chief materials used for clothing are:—

1. *From the Vegetable kingdom:*—Cotton, Linen, Jute, Indiarubber, and Guttapercha.
2. *From the Animal kingdom:*—Wool, Fur, Feathers, Silk, and Leather.
3. *From the Mineral kingdom:*—Small quantities of Iron, Brass, etc.

Materials from the Vegetable Kingdom.

(*a*) **Cotton** is obtained from the downy fibres attached to the seeds of the cotton plant, which grows freely in the United States of America, Egypt, and India. Those fibres are picked from the pods, separated from the seeds by machinery, then packed in bales and sent to Liverpool, Glasgow, Manchester, or London. After being cleaned and spun, the thread or yarn is woven into various cotton cloths, which are bleached, dyed, or printed, and may then be used for clothing or household purposes. Fustian, flannelette, velveteen, print, cretonne, jean, sheeting, calico, towelling, are cotton goods.

As a material for clothing, cotton has the following *advantages:*—

1. It is cheaper than linen, wool, or silk.
2. It is light.
3. It has hard fibres and will wear well.
3. It does not shrink when washed.

The *disadvantages* are:—

1. It is not a good absorber of moisture, therefore does not absorb the sweat of the body.
2. It is a better conductor of heat than wool, and consequently it allows the heat of the body to pass through it.
3. It absorbs odours readily.

(*b*) **Linen** is obtained from the fibrous stems of the flax plant, which is grown freely in North Ireland, Russia, Holland, etc. The plants are pulled up, and, after the seeds are gathered, allowed to ferment or rot on the ground, thus causing the soft material holding the fibres together to decay, in order that they may then be easily separated. The stalks are next beaten, combed, and afterwards spun into thread or linen yarn, which is woven into linen fabrics, *e.g.* sheeting, shirting, damask, diaper, holland, cambric, lawn, linen thread, etc.

As a material for clothing, linen has the following *advantages*:—

1. It is very cool for the skin.
2. The surface can be made smooth and glossy, which renders it very suitable for collars, cuffs, and shirt-fronts.
3. It is stronger and more durable than cotton.

The *disadvantages* are:—

1. It is a better conductor of heat than cotton.
2. It is a poor absorber of moisture.
3. It is more expensive than cotton.

The seeds of the flax-plant are commonly known as *linseed*, from which linseed-meal, linseed oil, and oil-cake are made. Oil is abstracted from the seeds and used for paints; the residuum, pressed into a solid mass, is utilised as a cake or food for cattle.

(*c*) **Jute** is a fibrous substance obtained from the stalks of two varieties of the *Corchorus* plant (*Corchorus capsularis*, and *Corchorus olitorius*) which is extensively grown in India.

The process of manufacture is similar to that of linen, but, as the fibres are coarser and more woody than those

of flax, the fabrics produced are much coarser. It is not much used as a material for clothing, but is employed to adulterate other materials with a view to cheapness, *e.g.* inferior carpets, rugs, and table-cloths.

Its principal *uses*, however, are for making:—

1. Sail-cloth.
2. Coarse sacking—millions of jute sacks called "Gunny bags" are exported from India, for packing corn and other merchandise.

(*d*) **Indiarubber** is an extremely useful substance obtained from the sap or milky juice of several tropical plants which grow in America, India, Africa, and the East Indies. This sap hardens when dried.

Its *qualities* are:—

1. It is soft to the touch.
2. It is extremely flexible and *elastic*.
3. It is tough and strong.
4. It is waterproof.
5. When heated, stretched out and allowed to cool thus, it loses its elasticity, but when heated again it becomes elastic.

Its *chief uses* are for making:—(1) cloth waterproof; (2) overshoes and goloshes; (2) elastic webbing for stockings, knee-caps, braces, garters, suspenders, etc. (Thin threads of indiarubber after being stretched and rendered inelastic, are woven with threads of other material and then allowed to recover their elasticity.)

Indiarubber is used for many other purposes, in addition to its use as a material for clothing.

Vulcanite is made by mixing crushed or shredded rubber with one-third its weight of sulphur, keeping the mixture at a high temperature for several hours and then allowing it to cool.

It is then hard, horny, and brittle instead of being elastic and soft. If we vary the proportion of sulphur we obtain materials of various degrees of hardness.

For clothing purposes vulcanite is used to make combs, bracelets, buttons, etc.

(*e*) **Guttapercha** is a substance resembling indiarubber in being waterproof, but differing from it, in that it will not stretch.

It is not so widespread in its origin, the trees from which it is obtained growing in very few places except the Malay Peninsula and Singapore.

For clothing purposes it is principally used for waterproof soles for boots.

Materials from the Animal Kingdom.

(*a*) **Wool.**

Is the natural covering of the sheep, llama, alpaca, and some varieties of the goat. It differs from hair in that hair is hard, straight and smooth, while wool is soft, curly, and has scales on the surface of the fibres. This last property enables wool to be felted by the interlocking of these imbrications or scales.

As a material for clothing wool has the following advantages:—

(1) It is a bad conductor of heat; this renders it useful for cold climates, for it prevents the loss of heat from the body.

(2) It is a great absorber of water. This is a most important property. During exercise, heat is produced and perspiration takes place, then the heat is reduced being used in the evaporation of perspired sweat. When the exercise is finished this evaporation still goes on, taking heat from the body, and if unchecked, the body becomes chilled on the surface. This lowers the vitality and micro-organisms are enabled to make a successful invasion of the mucous membrane lining the nostrils, pharynx, and throat, and set up a little inflammation in these parts. In common language the person acquires a cold through a chill experienced after sweating.

If dry woollen clothing is put on *after* exertion, the vapour from the perspiration is condensed in the fibres and in the pores of the wool, and gives up again the heat which had been used in turning it into vapour; the wool thus becomes

warm and the heat is not lost from the body, consequently it is not chilled. The water absorbed by the fibres themselves is called *hygroscopic* water. If, however, cotton or linen is worn the perspired vapour passes through to the external surface, without so much condensation taking place, and there is an actual loss of heat. The fibres themselves do not absorb water so that what water is retained is water of interposition and not hygroscopic water. The linen or cotton then feels wet to the touch.

(3) It is not a good absorber of odours.

(4) It is naturally rougher than cotton or linen and produces a little irritation of the skin which stimulates surface circulation. This roughness, however, would cause inconvenience to persons with sensitive skins. So in some respects this quality of wool may be called a disadvantage.

The *disadvantages* are:—

(1) It is more expensive than cotton or linen.

(2) The soft fibres shrink in washing, and after a time become smaller, harder, and possibly less absorbent.

To prevent this as much as possible, woollen materials should not be rubbed or wrung, nor should they be placed in water which is too hot. They should not be boiled, nor exposed to the hot sun when drying, Ammonia or borax should be used instead of soda to remove grease.

The chief kinds of woollen-goods are flannel, cloth, blankets, worsteds, and knitted goods. *Felt* is wool made up without weaving or spinning. The fibres are matted together by wetting and beating, the serrations on the surfaces interlocking with each other.

(*b*) **Fur.**

Is the natural covering of many animals which live in cold regions. It consists of a thick close-set covering of shorter hairs, interspersed with longer hairs which form the "over-hair." The quality of this over-hair determines the value of many of the furs; the over-hair of the fur of the silver-fox is fine and silky compared with that of the grey fox, and is more highly valued.

The chief fur-bearing animals are the ermine, sable, seal, Arctic fox, squirrel, chinchilla (or Chili cat), bear, beaver, otter, opossum, cat, rabbit.

The chief articles made of fur are jackets, cloaks, capes, boas, waistcoats, hats, caps, muffs, collars, and cuffs. Felt hats are made of rabbit fur which is mixed into a paste with a little glue and dye, and then moulded.

The advantages as an article of clothing are:

1. It is a bad conductor of heat, and is not of a close texture. This makes it one of the warmest kinds of clothing. (To get the greatest benefit from it the skins should be worn with the fur inside.)
2. It is elegant and ornamental in appearance.

The disadvantages are:

1. It is very expensive.
2. When not required in the summer it forms a harbour for moths and is spoiled unless special precautions are taken to preserve it.

(*c*) **Silk.**

Is a kind of gelatinous secretion with which the silkworm covers itself when about to change from the silkworm to the moth stage. (This substance hardens on exposure to the air and thus forms a thread.) The cocoon of silk envelops the chrysalis during the change. The cocoons are placed in hot water to kill the worm before it completes the change, for, as a moth, it eats its way out of the cocoon and spoils the silk by thus cutting it into short lengths. The silk is unwound from the cocoons, cleaned, made up into threads which are woven into silk fabrics such as silk cloth, satin (silk with a glossy surface), ribbon, velvet, plush, shawls. Gloves, stockings, and lace also may be made of silk.

The advantages as a clothing material are:—

1. It is a bad conductor of heat.
2. It is soft and smooth and thus is well suited for delicate skins.

3. It is much lighter than wool, and very suitable for underclothing.
4. It is durable, and is an absorbent of moisture

Disadvantages.

1. It is too expensive for ordinary wear.
2. It requires care in washing and drying.

(*d*) **Leather** is prepared from the skins of animals. Tanning or an equivalent process changes the skins which would be hard, brittle, and liable to decay, into a substance which is tough, flexible and does not readily decay. It is waterproof and is used for boots, shoes, slippers, purses, belts, etc.

The change of hides into leather may be produced by—

1. Action of tannic acid from oak bark or other similar vegetable substance, which changes the albumen and gelatine into insoluble tannates.
2. Using mineral astringents such as alum in the place of tannic acid.
3. Impregnating the skins with oil or fat. This is the method adopted in preparing chamois leather and all furs except sealskin.

Dry leather does not wear so rapidly as wet, therefore two pairs of boots should be in use to be worn on alternate days, and if this plan is adopted each will last much longer than if one pair be worn continuously.

(*e*) **Feathers** are sometimes used for ornamental purposes, but may be substituted for fur as a covering for the neck. Their chief use, however, is for stuffing pillows, cushions, and beds.

(*f*) **Glass, brass, iron** are used for ornament; *e.g.* buttons or buckles. Iron is also used as nails for boots.

Comparison of the Clothing Materials.

1. *Microscopic appearance.*

Under the microscope the fibres of wool, cotton, linen, and silk present well marked differences; see figs. 30, 31, 32, and 33.

Wool fibres show serrations or scales on the surface. Cotton fibres can easily be detected as they are flattened

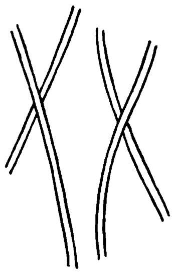


Fig. 30.—SILK FIBRES UNDER THE MICROSCOPE.

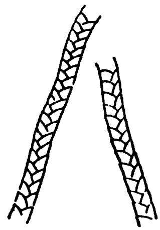


Fig. 31.—WOOL FIBRES UNDER THE MICROSCOPE.

and ribbon-like, and *are twisted* at frequent intervals. Silk fibres have no surface markings or scales. Linen fibres may be distinguished by their jointed structure.

2. *Conducting powers.*

The power of clothing to retain the heat of the body depends upon the material, its texture, and number of

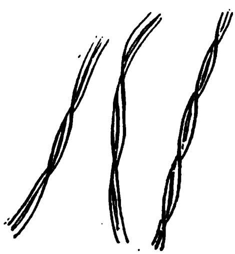


Fig. 32.—COTTON FIBRES UNDER THE MICROSCOPE.

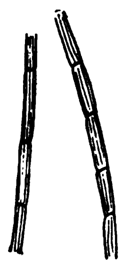


Fig. 33.—LINEN FIBRES UNDER THE MICROSCOPE.

layers. Wool is the worst conductor of heat, and then in order come fur, feathers, silk, cotton, and linen.

The closeness of the texture influences this power; loose, furry fabrics feel warmer than closely-woven silk and linen. Flannelette, although cotton, may be as warm as closely woven silk. The more layers of clothing the more layers of air intervene, and air is a bad conductor of heat. Colour of clothing only affects the outer heat. White absorbs least heat and is therefore coolest. Yellow, red, green, blue, and black follow in order. The colour does not affect the power of conducting heat from the body. Red flannel is no warmer than white.

3. *Power of absorbing moisture.*

This also depends upon the closeness of texture. Loosely woven cotton may absorb almost as much, if not more than closely woven woollen fabrics. Loosely woven flannel and woollen goods are, however, the best to use for under clothing.

Waterproof material has a great disadvantage in that it does not allow sweat to pass through, and the body becomes over-heated.

Clothing of Children and Adults.

In comparing the surface areas, and the weights of a child and an adult it is found that in the case of a child weighing 50 lbs. and an adult weighing 150 lbs., although the adult is three times as heavy, he has not much more than twice as much surface area. Hence bulk for bulk, the infant's body has a greater surface to lose heat from, which shows that very warm clothing is required. Infants in arms cannot take much exercise to assist in gaining heat, hence they require specially warm clothing.

In old age exercise cannot be taken so freely; the chemical changes in the body are less rapid so less heat is produced; hence older persons require warmer clothing than healthy adults at a working age.

The practice of leaving the arms and legs of children bare with a view to hardening them is decidedly wrong. Many cases of bronchitis are due to this. The clothing should be evenly distributed over the body. Women

frequently err too in this respect, the upper part of the body having scanty covering while the lower limbs are overloaded.

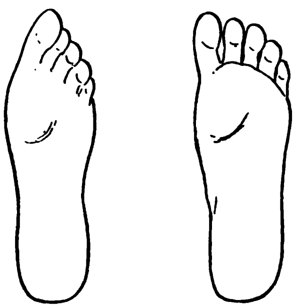
Injurious clothing and modes of dressing.

The chief faults in clothing may be placed in three classes.

1. Clothing which constricts some part or organ of the body.
2. Clothing which impedes the natural movements of the body.
3. Clothing which is excessive in weight, or unscientifically supported.

1. Constriction.

Tight shoes, sleeves, hats, collars, stockings, corsets, gloves, tight belts, and garters; these impede the circulation in the parts affected, and may produce congestion in other parts. Tight garters may produce varicose veins, tight boots produce corns and bunions. Tight corsets produce malformation of the organs of the body so that they cannot perform their natural functions as they should. Tight, heavy hats cause head-ache, depression, and baldness. Shoes with narrow pointed toes compress the big toe and cause a malformation of the foot (see fig. 34).



Foot deformed by pointed boots. Natural foot.

Fig. 34.

2. Impediments to movement.

Long and close-fitting skirts, tight sleeves, tight suits, cause a waste of energy by impeding the free movements of the body.

3. Weight and Mode of support.

Clothing which is too heavy wastes energy. Dress skirts which are too long and would trail on the ground require a good deal of energy to carry them in the hand. If allowed to sweep the streets, they carry dust into the house, and may help to spread infection during an epidemic. Heavy hats are unsatisfactory for all ages and for both sexes.

Clothing may be wrongly supported. All should be supported from the shoulders if possible, if not, then some from the hips. The practice of having a number of articles suspended from a belt round the waist is not a good one.

The boot heels should not be too high, or the foot is not in its natural position when bearing the weight of the body, and sprains are frequently due to awkward walking through high heels.

Poisonous Dyes.

The most important injurious dyeing materials are arsenic, chromium, lead, Scheeles green, Schweinfurth green, or Vienna green, and king's yellow, contain arsenic. These are used for dyeing cloths, etc. The greens, however, are not more liable to contain arsenic than other colours, as is commonly supposed.

The dyes for artificial flowers are frequently poisonous.

Chromium salts are used in calico printing and dyeing. They are also used in dying silk and linen.

Lead is used in the colouring of artificial flowers; in the weighting and dyeing of silk and alpaca; and in calico printing and dyeing.

Owing to the more recent improvements in the manufacture of dyes, however, there are less poisonous dyes used than formerly.

Effects of poisonous dyes.

1. They stain and discolour the skin, and frequently cause a rash.

2. They produce inflammation, eruptions, or a skin disease. Arsenic produces a brown pigmentation of the skin.

3. They may add poisonous material to the blood and derange the digestive and nervous systems. (See the effects of arsenic from wall-papers, p. 156).

SCHOOL HYGIENE.

This deals with the application of the general principles of Hygiene to schools. The principles regarding the site, construction, drainage, warming, and ventilation of buildings given in the various chapters of this work, are applicable to all classes of schools. As these, however, differ from dwelling-houses in that we have large numbers of children gathered in rooms for definite periods, for instruction or for other purposes, a special consideration of (*a*) ventilation, (*b*) lighting, and (*c*) furniture is essential.

(*a*) Space required.

To prevent the air becoming too vitiated it must be frequently renewed. To obviate the necessity of a *too* frequent renewal of the air, which may cause draughts, sufficient space must be allowed for each pupil occupying a room. The Board of Education require a floor space of 9 square feet for each infant, and of 10 square feet for each older scholar, and the height of a room should not be less than 10 feet, so that 90 or 100 cubic feet of space forms the minimum allowance for schoolrooms. This, however, is far from sufficient. If a space of 100 cubic feet is occupied by one person, the air will require changing nearly 30 times per hour if we are to supply the 3000 cubic feet of fresh air requisite to keep the CO_2 below the limit of permissible impurity (see Chap. II.). *If the air is to be changed only three times per hour* (which may be done without perceptible draughts), each child would require nearly 1000 cubic feet of air space, and none of this calculated air space should be more than 15 feet above the floor. As the expense of providing this space would be excessive, less space has to suffice, which fact renders it very important that whenever possible (*e.g.* during an

interval), the windows should be opened to their widest extent to flush the room. When this course is adopted a space of 300 to 400 cubic feet is sufficient.

For sleeping accommodation at a residential school, 500 cubic feet should be the minimum allowance per pupil.

(*b*) Lighting.

Every part and corner of a schoolroom should be fully lighted. The light should, as far as possible, come from the left hand, so that in writing the shadow of the hand and the pen will not obstruct the view of the work. If light from the left side is unattainable, then light from the right is the next best. Light from the front is dazzling to the eyes of the pupils, while light from the back is not pleasant for the teacher, and causes the shadow of each pupil to fall on his work. Small panes, or any arrangement which obstructs the light should be avoided.

Windows should extend to about 4 feet from the floor, and some, if not all, should reach to the ceiling. If the top of the window is made to open, foul air collected near the ceiling may be got rid of readily. The window area should be from $\frac{1}{10}$ to $\frac{1}{6}$ of the floor space.

For *artificial lighting* the incandescent electric light is by far the best. As a guide to the number of lights required, for every 100 square feet of floor space, one 16 candle-power lamp placed 8 feet above the floor will give a dull illumination, two will give a good illumination, and four will give a brilliant illumination. The light should be shaded so that it does not fall directly on the eye, but is reflected from surrounding objects.

If gas be used some form of incandescent burner is requisite, the flickering of naked gas flames, (due to variations of pressure or to water in the pipes) is very exhausting to the eye when a pupil is reading.

(*c*) Furniture.

One of the most important articles of school furniture is a good desk. Various patterns are now on the market, some fairly good, others decidedly bad. *The desk and seat*

should be suited to the size of the pupil. The seat should be wide enough to form a good support, and the height should not exceed the length of the leg, measured from the bend of the knee to the heel. Every seat should have a support for the back of the pupil.

The height of the desk should be arranged so that the pupil will not have to stoop to it when writing, nor should it be so high that he must raise his elbow and shoulder to reach up. Either of these defects may produce a curvature of the spine. The desk top should be inclined a little, an angle of about 15° is sufficient. For writing, the edge of the desk and of the seat should be in the same vertical plane, while for standing this is impossible, so that adjustable desks are necessary to suit all kinds of work.

Blackboards should be arranged so that the light falling on them is not reflected directly to the eyes of the pupil.

Care of the Eyesight.

The eye consists of a double convex lens, the crystalline lens, protected in front by a circular diaphragm, the iris, and having a sensitive screen, the retina, on which the images of external objects are cast. The impressions conveyed to the brain from these images give rise to the sensation of sight.

Under ordinary conditions an arrangement of this kind would only enable objects at a certain definite distance from the eye to be seen distinctly, for as the distance between the lens and the image on the retina is fixed so also the distance between the object and the lens must be fixed. The eye, however, has the power of *accommodation*, for the curvature of the surface of the lens may be altered so that images of objects at various distances may be received in turn on the retina.

The condition of distinct vision of any object is that a clearly defined image of it is formed on the retina. If the axis of the eye be too long, the eye may not have sufficient accommodating power to enable the images of distant objects to fall on the retina, although objects near may be distinctly visible. An eye of this character is said to be

short-sighted or *myopic*. Another defect of vision is *long-sightedness* or *hypermetropia*. In this case the axis of the eye is too short and when the eye is at rest the image of a near object would be formed *behind* the retina and thus a blurred and indistinct image is formed *on* it and the object is seen indistinctly. The use of proper spectacles overcomes these defects and prevents the straining of the eye that inevitably follows upon these conditions. The lenses of these should be arranged that, acting in combination with the lens of the eye, images of objects will be formed on the retina. Convex lenses are generally required for long-sight, and concave lenses for short-sight.

Another important defect of vision is the long-sightedness due to advancing age. This is called *presbyopia* and is due to a gradual decrease in the accommodating power of the eye. This may require two pairs of spectacles, one for near objects as for reading, and another for use when viewing distant objects.

In some cases of defect of vision the magnitude of the defect may not be the same for both eyes so that lenses of different focal length may be required to absolutely correct the vision.

The eyes of all pupils should be periodically tested by means of test types. A card specially arranged with letters of various sizes may be readily obtained at an opticians. For normal vision, letters $\frac{5}{16}$ of an inch in height should be distinguishable at a distance of twenty feet. If the letters of this size are not recognised, the next size should be tried and the smallest type distinguishable should be noticed. If there are any defects the parents should be communicated with, so that spectacles may be obtained if necessary. It is now becoming recognised by the more important Education Authorities that the eyes of children should be periodically examined by a medical officer of the Authority.

If one of the eyes is a little defective, both try to act in concert to produce distinct vision, and this produces eye-strain which is recognised by various pains and aches, and if this is continued, permanent injury may be produced, hence the necessity for testing the eyesight so

that defects may be provided for when they first make their appearance.

Some of the school surroundings which affect vision are:—

1. Defective lighting of the rooms;
2. Light falling directly on the eyes;
3. The colour of the walls; a *pink* tint does not rest the eye while a cream colour or a French grey will do so, or a light green may be used.
4. The use of books printed in too small type, or with unleaded type so that the lines are too close together;
5. Close attention for too long a time at one sitting;
6. The employment of microscopic stitches in needle-work, or of coloured material which produces eye-strain.

As the eye is so useful, and yet is easily injured, everything possible should be done to preserve its powers. Therefore:—

(*a*) Avoid conditions of work which are likely to injure the eyesight;
(*b*) Test the eyesight periodically to detect any defects at once;
(*c*) Have spectacles obtained specially suited to remedy any defects which are found.

Ventilating and Warming Schools.

The paragraphs dealing with the subject of Ventilation and Warming, together with the extracts from the ***Report on the Cost and Efficiency of the Heating and Ventilation of Schools*** drawn up by Dr. Carnelley for the Dundee School Board, which are given in Chapters II. and VIII. may be referred to for this.

PRACTICAL WORK ON CHAPTER V.

1. **To compare the absorptive powers of cotton and wool.**

(*a*) Take equal weights of dry calico and flannel. (*b*) Soak in water. (*c*) Wring out and weigh again.

The wool will be found to have retained a greater weight of water in its pores than the cotton.

2. **To compare the conductive powers of clothing materials.**

Take a piece of dry linen and a piece of dry flannel. Place two similar thermometers in hot water. When they have acquired the temperature of the water, remove them rapidly (with as little loss of heat as possible) and wrap the bulb of one in linen, and the other in flannel. Leave for a few minutes then examine the readings to see which has lost the greater amount of heat.

CHAPTER VI.

THE DWELLING-HOUSE.

SELECTION OF A SITE.

The chief points affecting the healthiness or unhealthiness of a site for a dwelling-house are :—

I. Kind of soil and subsoil, with rocks underneath.
II. Aspect and elevation.
III. Distribution of water in the soil.
IV. Action of the soil on air.

I. Influence of the soil on health.

The soil is formed by the disintegration of the rocks by (*a*) chemical, (*b*) physical, and (*c*) organic agency.

(1) The soil may contain a number of micro-organisms present in the humus or organic matter. Some of these are harmless, while others, *e.g.* certain bacilli, if allowed to obtain an entrance into the human body, are productive of such diseases as tetanus and malignant oedema.

(2) The physical properties of the soil have a marked influence.

Permeable soils, *i.e.* those which allow the water falling on them to soak in and flow away, are usually dry and healthy.

Impermeable soils, *i.e.* those which do *not* allow the water to flow away, are damp and unhealthy, often causing colds, sore-throat, rheumatism, and predisposing the body to phthisis or consumption.

(3) "*Made*" soils, consisting chiefly of a rubbish deposit, should be avoided, as the bad-smelling gases arising from the decomposition of organic matters may cause a predisposition to disease.

Clay soils, on account of their impermeability, are not satisfactory as surface soils, because they tend to retain the water which may accumulate on them; and, as subsoils, they may retain the water which percolates the more porous layers overlying them. These disadvantages, however, may be removed to a great extent by a well executed system of subsoil and surface drainage.

Sandy and gravel soils, on account of their loose porous nature and permeability, are warm and are much dryer than clay soils.

The disadvantages are :—

(*a*) The presence of a little moisture with warmth and some organic matter are precisely the conditions favourable to the life of micro-organisms.

(*b*) The water supply may have to be taken from a shallow well, and this may be rendered impure if the sand overlies an impermeable layer.

(*c*) The permeability renders the soil liable to pollution, *e.g.* from a leakage in a faulty sewer.

In addition to draining subsoils, the drying of the site may be assisted by:

(1) Clearing out the water-courses.
(2) Removing obstructions.
(3) Making fresh channels.

By these means the surface water may be allowed to flow away freely instead of sinking into the ground and thus raising the level of the ground-water.

Heat of the soil. Some soils have a less specific heat than others; *i.e.* they do not require as much heat to raise their temperature. These are spoken of as *warm* soils. Soils which retain water are usually *cold*. Clay soils are usually cooler at the surface than less moist soils on account of the great specific heat of water; and the lower layers are also cooler, for water is a bad conductor of heat

and does not transmit it readily to them from the surface layers.

In considering the powers which the soils possess of (*a*) absorbing, (*b*) retaining, (*c*) radiating heat, it is found that the powers of absorption and radiation depend partly on the colour of the soil, and the vegetation growing on it, *e.g.* a light-coloured soil reflects light and heat, while a darker one absorbs more.

Sand warms more rapidly than clay, and in addition to having a low specific heat, the organic matter frequently present helps it to absorb heat better.

Soils may obtain a little heat from chemical action which takes place in them.

In choosing a site for a house a warm soil is preferable to a cold one.

II. The Aspect.

The aspect of a house has an effect on its healthiness. If possible, it should face south or south-west, as the front rooms will obtain a larger amount of sunshine than if facing in any other direction.

The presence of sunshine acts as a restraint on the growth of some micro-organisms and is generally beneficial to the healthiness of a house and its inmates. In England, if exposed to the north or north-east, the cold winds from the wide expanses of land in Europe and Asia are felt.

Surroundings. The house should not be situated near brick-yards or any offensive works. It should have a free circulation of air round it, but should be sheltered from cold winds.

Elevation. An elevated site is better than a low-lying one, as the latter is more likely to be damp. The elevation, however, is only relative, for a site on a hill-side, although elevated above the valley, may be damp, because it is relatively lower than the hill-top, and water from the higher land may flow to it.

An elevated site is easier to drain than a low-lying one —there is plenty of fall in the former for the drains to carry off the water

III. Distribution of water in the soil.

The rain which falls may be divided into three parts thus:—about (*a*) $\frac{1}{3}$ passes off in evaporation;
(*b*) $\frac{1}{3}$ flows over the surface to form streams and rivers;
(*c*) $\frac{1}{3}$ sinks into the earth.

The result of the sinking is that the lower layers of the soil are saturated with water. The depth of this saturated layer depends upon the kinds of soil or rocks upon which the rain falls. If there is a deep layer of porous material, the water goes on sinking deeper and deeper; but when there is an impervious layer, *e.g.* a bed of clay, which arrests the downward movement, then an underground reservoir of water is provided, the pores of the soil being saturated with it.

This provision is utilised when a well is sunk. (The bottom of the well is below this level and water enters the well, filling it to the level of the water in the saturated layers around it.)

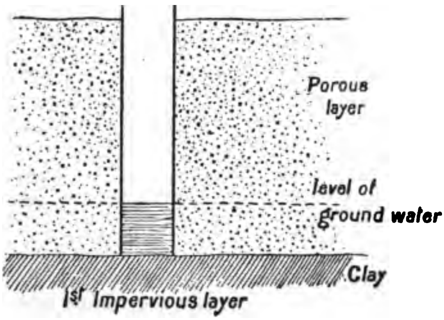


Fig. 35.—Shallow Well.

The *level* of this *ground-water* should not be within a distance of 10 feet from the surface; it may be hundreds of feet below. If it reaches the surface a *marsh* is formed, the site is therefore damp and unhealthy. To keep the level below 10 feet, drains should be put in at that depth to carry off all water in the soil above them.

The level should not be subject to fluctuations which may lead to communication between well-water and impurities that are contained in cess-pools, or in the upper layers of soil.

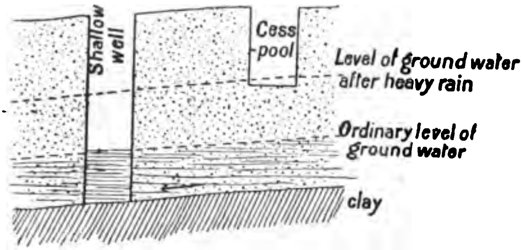


Fig. 36.—FOULING OF WELL CAUSED BY RISE OF GROUND WATER.

The cellars, in houses situated near a river, may be flooded when the river rises, as the level of the ground-water rises with it.

IV. Action of the soil on air.

Ground-air is the name given to the air in the interstices of the soil. It contains less oxygen and more carbonic acid gas than the ordinary air, and may contain gases resulting from a decomposition of organic matter in the soil. Occasionally, carburetted hydrogen is present, and if sulphides are contained in the water or soil, we may find sulphuretted hydrogen.

A rise in the level of the ground-water forces ground-air from the pores of the upper layers carrying with it any germs, that are in the soil, to the detriment of health.

MATERIALS USED IN BUILDING.

The chief materials used for the foundations and walls of buildings are obtained from the earth, either in

(*a*) Blocks which are naturally held together;
(*b*) Materials that can be artificially consolidated.

Sandstone, limestone, granite, and other kinds of stone are used—each district utilising its natural resources, *e.g.* granite houses in Aberdeen, limestone in Derbyshire.

The durability of stone depends upon its resistance to atmospheric influences.

Red sandstone does not successfully resist these influences, *e.g.* Chester Cathedral is built of this material, and is constantly needing repairs in one part or another.

Magnesian limestone is frequently used, and was recommended by a Royal Commission, after examining quarries and rocks of various kinds, for building the Houses of Parliament. Experience has shown that the atmosphere of the City of London affects the stone, which already shows signs of decay.

Bricks are made of clay, which is dug up, ground, and well mixed by a machine to render it even in texture; then moulded, dried and finally baked in kilns. The colour depends upon the composition of the clay and the degree of burning—ordinary *red* bricks contain ferric oxide (Fe_2O_3); Staffordshire *blue* bricks have been heated to such a degree that the ferric oxide appears to be changed into black oxide (Fe_3O_4). These latter are extremely hard and much less porous than ordinary bricks. *White* bricks contain very little iron, and frequently chalk is ground with the clay.

Terra Cotta is made from clay, which is more carefully prepared than for ordinary bricks. It is used for the ornamental parts of houses.

Firebricks, containing silica mixed with clay, are almost infusible and are used for lining fire-places. The best fire-clays are found under coal beds—the presence of carbon from mineralized vegetation appears to be an improvement.

Mortar consists of a mixture of water, lime, and sand. When it is exposed to the air, the water evaporates and the lime hardens, becoming changed into carbonate of lime owing to the absorption of CO_2 from the air.

Cement is made of clay and lime which have been ground up and heated together, so that silicate and aluminate of

lime are formed by the reaction of the aluminium silicate (clay) on the lime.

Roman cement is obtained by heating *naturally* occurring mixtures of clay and lime.

Portland cement—so called from the resemblance in colour of blocks constructed of it to Portland stone—is made by *artificially* mixing chalk and the river mud of the Thames and Medway. It sets quicker and becomes harder than Roman cement.

These cements when mixed with water form an extremely hard stone, owing to the combination of water with the aluminate and silicate of lime.

Concrete is a hard substance, consisting of broken bricks and stone embedded in cement. It is used for window-sills, foundations of buildings, artificial stone and road-making.

Imitation Terra Cotta is made of concrete with powdered brick instead of larger pieces of brick. It is more durable than the real article.

Roofing Materials.

Roofs may be covered with (1) thin slabs of stone, (2) slates, (3) tiles, (4) lead, (5) zinc, (6) galvanised iron, (7) vulcanite, (8) thatch.

(1) *Thin slabs of stone* ($1\frac{1}{4}$ to $1\frac{3}{4}$ inches thick) are used to cover houses, where there is an abundance of easily split rocks.

This roof-material has the disadvantage of requiring a very strong framework to bear the enormous weight.

(2) *Slate* is a hard impervious rock, which can be split into much thiner layers than ordinary rocks. This enables it to be used with a lighter framework and an excellent roof can be made with good slates. They vary in quality some being brittle, while others are soft.

The *qualities* of a good slate are:—

(*a*) Absence of streaks and flaws, or soft and scaly appearance;

(*b*) Hardness without brittleness;

(*c*) Small capacity for absorbing water, *i.e.* not more than 6 per cent. in 24 hours, if allowed to stand in it; and if at half its depth, the water should not rise to the top.

If these tests are stood, there will be no danger of the roof letting in water or absorbing water and making the wood supports damp.

(3) *Tiles* are made of clay, which has first been worked to render its structure homogeneous, and afterwards baked.

The disadvantages are:—

(*a*) They are very porous—if made of ordinary clay—and absorb a larger amount of water than slates, thus making the rafters damp.
(*b*) They are heavy and require strong supports.

Some of the best roofing tiles are made at Broseley in Shropshire. These are baked like the Staffordshire blue bricks, and are not so porous.

(4) *Lead* is used for covering irregularly shaped surfaces, *e.g.* gutters, joinings of slates, flashings, etc., and is easily worked and moulded to shape. It is unsuitable for ordinary roofing on account of

(*a*) Expense;
(*b*) Great weight, which would require very strong supports.

(5) *Zinc* is lighter and cheaper than lead, but it is not suitable for roofing dwellings. It requires fixing with nails coated with zinc, or when the roof is wet galvanic action will be set up between two dissimilar metals in contact, and the zinc will be dissolved. In addition allowance has to be made for the expansion and contraction of the metal due to variations of temperature.

(6) *Galvanised Iron*—*i.e.* sheets of iron which have been dipped in melted zinc—is sometimes used for roofs. Iron is an unsuitable material, for rust is formed and this peels off allowing the next layer to be acted on, and thus the rust eats through. Zinc and lead oxidise when exposed to the air, but the rust does not peel off, it forms a thin protective coating which prevents the action going deeper.

For this reason, sheet iron is usually coated with zinc or tin.

(7) *Vulcanite* is formed of indiarubber and sulphur. It forms a very light roofing material and from recent experiments it promises to be durable.

(8) *Thatch* is chiefly used in country districts. The upper rooms are warmer in winter and cooler in summer, than under a slate roof.

The disadvantages are :—

(*a*) The necessity for very strong supports;
(*b*) Liability to harbour birds and mice;
(*c*) Danger in case of fire.

Foundations.

These should be arranged :—

(1) To give stability, and
(2) To keep the upper part of the building dry.

If the house cannot be "founded on the rock" owing to the depth of the surface soil, this should be dug out, and concrete used to form a hard substantial layer. The depth and width of this layer will depend upon the height of the building, and the weight to be supported.

Concrete has the advantage of being :—

(1) Firm and stable;
(2) Impervious to moisture.

In places where the ground is liable to subside (*e.g.* Northwich, owing to the removal of salt rock in brine by pumping) long beams of timber are bolted together and placed to form a framework under the walls; so that if the ground under part of a wall sinks in, the part over the opening remains uninjured, as it is on the timber. If the whole house sinks, it can be raised bodily by means of screwjacks and a hydraulic lift, while the hole underneath can then be filled up. *Timber*, however, is apt to decay

and the houses cannot be taken to a great height, as the weight of the walls will crush timber when it decays. It would be preferable to use *wrought-iron girders* for this purpose. *Cast-iron* is unsuitable on account of its brittleness. Cast-iron is, however, the best material for upright supports.

Where houses are built *on "Made" soils*, it is necessary to cover the whole site within the walls with a 6-inch layer of concrete, to prevent

(*a*) Dampness, and
(*b*) Ground-air from rising into the basement, bringing with it gaseous emanations from decaying organic matter in the soil.

This would be in addition to the bed of concrete for the purpose of transmitting the weight of the walls to the ground.

The danger of ground-air finding its way into dwellings is intensified in towns, owing to the impervious coverings of the ground by the foundations of the best-laid streets.

Should there be a quantity of ground air expelled from the soil on account of

(*a*) Change of temperature, or
(*b*) Rise of the level of ground-water,

the unprotected surface of the soil under the houses is the only place through which it can find a way.

In houses with no gas laid on, cases of illness have been caused to the inmates, by an escape from the gas mains under the streets.

Methods for preventing Walls becoming damp.

Damp-proof course. The walls, whether of stone or brick, are very absorbent, and water from the soil is carried up them by means of capillary attraction, causing the walls to be damp. (An ordinary brick can take up a pint of water in its pores.) This evaporates when the rooms are heated by a fire, and unless a constant interchange of air is provided

by keeping open the windows and doors—thus allowing the watery vapour to escape—the inmates are living in a vapour bath which may be productive of cold or other illness. This climate is not suited for windows and doors to be wide-open daily, therefore it is necessary to insert a layer or course—impervious to water—just above the ground-level. This is called a **damp-proof course.**

The materials used may be as follows:—

(1) A layer of cement, spread on when the wall is a few inches above the ground-level and completely covering the top of it; *or*
(2) A layer of slates embedded in cement; *or*
(3) Asphalt, or coal tar, or slates embedded in either of these.

One of the best methods is to have a layer of slate followed by a course of Staffordshire blue bricks, both of these materials being set in cement.

Second damp-proof course. If the walls come in contact with the soil above the damp-proof course—as happens when there is a cellar to be kept dry, and the damp-proof course is below the surface of the ground—a second course should be laid *above* the surface of the ground.

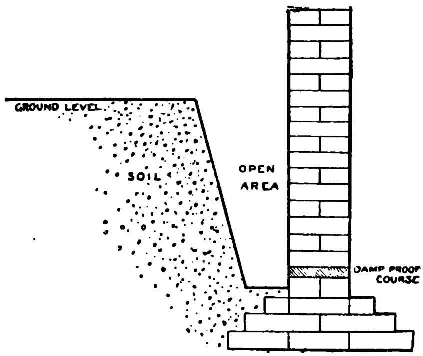


Fig. 37.—Showing Damp-proof Course and Open Area.

Open area.. A very useful method is to excavate the soil from around the walls so that there is a trench round the house, which forms an "open area" and helps to keep the walls dry. See fig. 37, which shows a damp-proof course and an open area.

Dry area. Another method which may be adopted when the soil comes above the damp-proof course is to make what is called a "dry area."

A thin wall is built against the soil, not less than 8 inches from the main wall. It may be parallel to the main wall, or curved as shown in fig. 39. The dry area

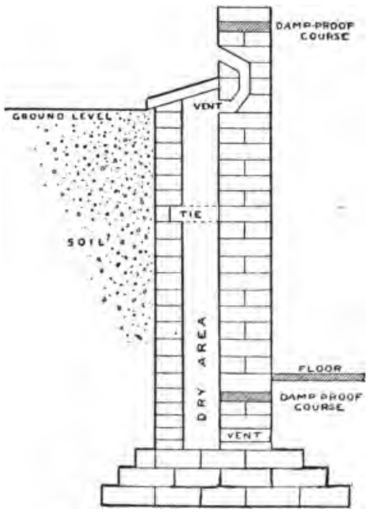


Fig. 38.—Showing Damp-proof Course and Dry Area.

(Outer wall straight or curved).

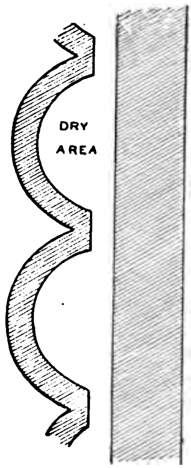


Fig. 39.—Plan of Wall in Fig. 38, showing outer wall curved.

between the two walls is covered above the ground level with stone or slate, and being drained and ventilated it forms an efficient preventitive of damp. Fig. 38 shows a "dry area" and two damp-proof courses. Fig. 40 shows another method of constructing a dry area.

The wall is made hollow, having the outer part

thicker than the inner. This tends to keep the house

(*a*) *Dry*, for the damp cannot cross the air-space, and
(*b*) *Warm*, as the heat from within is not conducted away so readily.

The two parts of the wall may be united by iron ties.

Cellar or Basement Floors.

In addition to concrete a layer of asphalt may be spread. This forms a smooth non-porous floor for the cellar or

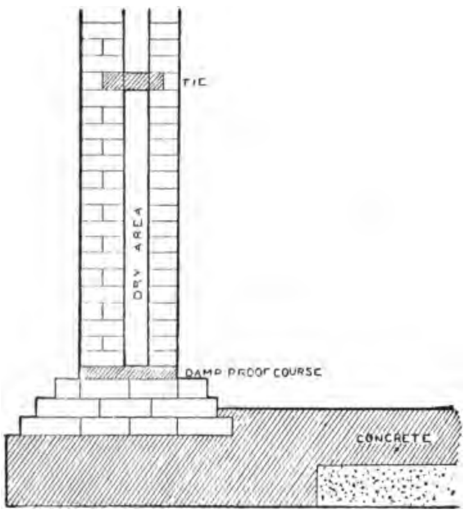


Fig. 40.—Showing Damp-proof Course and Hollow Wall.

basement, and keeps it dry. In many cellars no precautions are taken; the bricks are laid on the soil itself. This causes them to be damp and to have a disagreeable odour.

A rise of ground-water causes an upward movement of the ground-air, and to prevent this passing into the house the floor should be impervious to gases as well as to water.

Kitchen floors.

Ordinary boards may be used for a kitchen floor, but may harbour beetles, being warm and dry.

A *wood-brick* floor, laid on concrete, is much better and warmer than either *clay bricks* or *tiles*. If the wood-bricks are laid with the end-grain upwards they last longer, but are not easily cleaned, being liable to retain stains, for liquids spilled on them soak down the grain.

Tiles are easily cleaned, but are good conductors of heat and consequently conduct it from the feet, thus producing a feeling of cold in them.

Other floors.

These may be made of wood-boarding, viz., (1) spruce, (2) pine, (3) pitch-pine, and (4) oak.

(1) *Spruce* is sometimes known as *white fir* and the boarding as white deal.

(2) *Pine* is in reality red and yellow deal and not fir.

The above kinds of wood are easily worked, but the white deal is not so durable as the others.

(3) *Pitch-pine* is hard and heavy, and being highly charged with resinous substances, it is very durable. The resin gives it a tendency to stick to the tools, causing it to be more difficult to work than the other pines. The beautiful figure of its grain makes it suitable for ornamental work, and its durability renders it suitable for sills or flooring, which will have a good deal of wear.

(4) *Oak* is a harder wood than deal and more expensive. Canadian oak is much easier to work than English oak, but is not so durable.

Oak is very suitable for stairs and where a specially smooth floor is required.

The wood used for floors should be well-seasoned, or, owing to shrinkage, spaces will soon be formed between the boards. Dust and rubbish may fall into these, and be stored up to decay, causing danger to health. To prevent this, it is advisable to use *tongued-and-grooved* boards, *i.e.* one edge of each board is ploughed to form a groove, and the other edge has a projection or tongue cut, so that the tongue of one board will fit into the groove of the next. Sometimes both edges are grooved and a loose strip is used to fit into both boards which join.

Dry rot is caused by the growth of fungi, the spores of which, floating about in the atmosphere, may alight on timber. If the conditions are favourable, these germinate, insert their roots in the timber, the constituents of which they decompose, and so obtain their nutriment. These plants rapidly spread over the whole of the timber and attack other timbers in the vicinity causing them to crumble. They may spread to the bricks and plaster and thus endanger the whole structure. The favourable conditions are (1) a warm, humid atmosphere, (2) insufficient ventilation, and (3) the presence of any green sap in the timber. All floors should, therefore, be made of well-seasoned wood and should be well ventilated.

Slag-wool or Silicate cotton is sometimes used between the ceiling of a room and the floor above it. This is a by-product of iron-smelting. Being a bad conductor of sound and heat, the rooms thus separated, are more conducive to health, for the inmates of one are free from annoyances from others.

Floor coverings.

It is essential to health that all floor coverings should be easily removed. *Carpets* should not cover the whole floor, as their removal necessitates taking out every article of furniture from the room, consequently they are liable to be left down for a long time without cleaning. They should cover the central part of the floor, and the outer border can be polished.

Linoleum is a useful floor covering. It consists of a preparation of linseed oil and ground cork intimately mixed and spread in a uniform layer over one side of a sheet of rough jute canvas. Colouring matter may be added when mixing, and a pattern may be printed after spreading on the canvas.

Oil-cloth is made of coarse canvas which is first coated with size and afterwards covered with a layer of very thick paint, laid on with a trowel and well worked in. Both sides of the canvas are treated in this way; and when one layer is dry, additional ones are similarly treated. Finally, the pattern is printed on.

Wall coverings.

The surface of the walls should be:—

(*a*) *smooth*, so that the dirt will not lodge on projections, and

(*b*) *non-absorbent*, so that they will not become damp.

Glazed bricks form an almost ideal surface for staircases if they are properly set.

Plaster. This is made of lime, sand, and water, mixed with cow's hair to make it hold together better. The walls are covered with a layer of coarse plaster upon which is placed a thin layer of finer plaster. When dry the plaster may be coated with colour-wash, lime-wash, paint, or paper.

Paint is much better than the washes and can be cleaned, but it is more expensive and will not stand much scrubbing. Persons should never sleep in a newly-painted room as the vapours from the paint are unhealthy.

Colour-wash. Before a fresh coat of lime-wash or colour-wash is applied, the old layer should be removed by scraping, as it has absorbed a large quantity of vapours from the air, and, if left on, there will be layers of dirt and colour-wash accumulating. The colour-wash is made by mixing whiting and water, together with a little colouring matter. Lime-wash is made by mixing quicklime (not whiting) and water. In each case a little size should be added to make it more adhesive.

Cements. There are several kinds of cement used as wall coverings or decorations, (1) plaster of Paris, (2) Keene's cement, (3) Parian cement.

(1) *Plaster of Paris* is obtained by heating gypsum to 120°F. to drive off the water which is combined with the sulphate of lime: if mixed with water they reunite and form a hard substance. As it is easily moulded, and does not contract on setting it is used for cornices and other ornamental work.

(2) *Keene's cement* is made by grinding up a little alum with plaster of Paris, and is used for walls.

(3) *Parian cement* consists of borax ground up with plaster of Paris. This forms a splendid wall covering but is expensive and liable to crack.

Lincrusta-Walton—an invention of Mr. Walton—is an excellent wall covering. It consists of a preparation of oxidised linseed oil and cork or other thickening material, upon which is embossed some pattern. This is very durable and almost impervious to moisture, but it is expensive and dust accumulates on the projections formed by the raised patterns.

Wall-papers. Although these may be artistic in appearance, they form a very poor covering as they are—

(1) *Porous* and *absorbent*, therefore dust and dirt adhere, and

(2) *Unwashable*, unless varnished.

These disadvantages are accentuated, from a sanitary point of view, if another paper is pasted on without removing the last one.

The advantages of paper are—

(1) It is cheap.

(2) It may be used to produce an artistic effect.

Poisonous colouring matter. If the paper has been printed with arsenical pigments—especially when the colours adhere loosely—the arsenic gradually passes into the air and may be slowly absorbed into the system. The effects produced are—

(1) Congestion and irritation of the mucous membranes;

(2) Redness and irritation of the conjunctiva;
(3) A peculiar eruption of the skin; and
(4) Derangement of the digestive system with diarrhoea.

The treatment for the above is generally :—

(*a*) Removal from the poisoned atmosphere, and
(*b*) Administration of tonics.

It is a popular belief than only green papers contain arsenic, but it may be present in any colour.

EXPERIMENTAL WORK ON CHAPTER VI.

1. **To show the porosity of bricks.** Take an ordinary brick, heat it for some time in a fire to thoroughly dry it. (It takes some time for the interior to become dry.) Then weigh it. Next place it in a pail of water for an hour or two. Take it out, dry it with a cloth and weigh again. The increase of weight will give the weight of water absorbed. If thoroughly dry to commence with the brick will be over 1 lb. heavier. (A pint of water weighs 1¼ lbs.)

2. **Comparison of bricks and slates.** Take a slate and test it in the same way. (If the slate breaks in the fire weigh the pieces). The slate will be found to absorb very little water.

3. **To test wall paper for arsenic.** Fill up a flask for the preparation of hydrogen gas, using a delivery tube having a jet. In the flask place some *pure* zinc (not commercial zinc), and pour on this some *pure* dilute sulphuric acid. When the hydrogen produced has displaced the air from the flask, light the gas now being produced, at the jet. Put some of the suspected paper into the flask, or better still, pour in a solution made by boiling some of the paper. If arsenic be present in a short time AsH_3 will be formed, and the escaping gas will burn with a bluish flame. If a cold porcelain dish be held in this flame, a bright black stain is produced on the dish.

N.B.—Antimony also produces a black stain in the same way. The stain produced by arsenic, however, is dissolved by a solution of sodium hypochlorite (NaOCl) while the stain produced by antimony is not dissolved by this reagent.

CHAPTER VII.

HEATING.

Heat is a form of energy. It produces a vibratory motion of the molecules of bodies, and this may be transmitted from one part of a body to another, or from one body to another.

Heat may be transmitted in three ways:—

(1) *Conduction*, i.e. the motion is transmitted from one molecule of a body to another without a change in their relative positions. In this way, heat passes from one part of a *solid* body to another.

(2) *Convection*, i.e. transference of the vibratory motion of the molecules which at the same time change their relative positions.

If a fluid be heated from below, the lower layers acquire more heat energy and the molecules tend to separate; the fluid thus becomes less dense than the superincumbent layers, and is drawn downwards by the force of gravitation with less force than equal volumes of the denser fluid above; hence the upper layers move downwards, and the lighter heated layers are forced upwards.

This action is continuously repeated on the successive layers of the fluid which become heated in the lower part, so that in time the whole fluid is heated.

This is the process whereby heat is transmitted to upper layers of *liquids* or *gases* when heated from below. The molecules in a liquid have not so much cohesion as those in a solid, hence they can change their relative positions, (which is impossible in a solid). The ascending currents of heated fluids and the descending cooler ones are known as *convection currents*.

(3) *Radiation*, i.e. transmission of heat through space in rays or straight lines, without warming the intervening space.

By this means, heat passes from the sun to the earth, or from an open fire to objects in its vicinity. This is a very important method in connection with the heating of dwellings. The radiant heat from the sun does not warm the air through which it passes, but, after being absorbed by the earth and other bodies it is radiated again.

The heat radiated from the earth consists of what are called *dark heat rays*. It is these which warm the air and the smaller objects it contains.

An illustration of the difference between these different heat rays may be seen in a glass-house.

The *direct* rays from the sun pass through the glass roof, but the *dark* rays radiated from objects in the room cannot pass through the glass, and are imprisoned in the room, thus greatly increasing the temperature.

Fuel.

Fuel includes the combustible substances we use to produce heat. The chief are (*a*) coal, (*b*) coke, (*c*) peat, (*d*) wood, (*e*) coal gas, (*f*) oil, (*g*) artificial fuels.

(*a*) **Coal** is *mineralised vegetation*, consisting of plants, which flourished in the Carboniferous era, but have been changed by the action of heat and pressure.

(*b*) **Coke** is the residue of coal which has been distilled to obtain coal-gas.

(*c*) **Peat** is decayed vegetable matter, similar in origin to coal, but it has not been changed so much. It is formed in bogs and marshy places.

(*d*) **Wood** is obtained from the harder parts of plants.

Each of the above materials consists of substances whose molecules have been built up under the influence of the light and heat of the sun, when the plants were growing. The solar energy is changed into chemical energy. When these substances are burned the complex molecules break down, and relatively simpler molecules are formed. (These are chiefly CO_2 and H_2O). These require less energy to hold their atoms together than the original molecules, and the difference is changed into heat energy.

(*e*) **Coal gas** is obtained by the distillation of coal in closed retorts. The coal is heated without contact with air, and the products of the destructive distillation are made to pass through condensers in which they are cooled, and coal tar and ammonical vapours are condensed and collected. The gas is then passed through purifying chambers containing moist slaked lime, and ferric hydrate. These remove gaseous sulphur compounds, and the lime also removes CO_2. The gas is then stored in gas-holders or gasometers for use. The coal left in the retort becomes **coke**. **Charcoal** is produced from wood, this being heated to a red heat out of contact with the air.

(*f*) **Oil.** Liquid fuels are obtained from Pennsylvania, Baku, and Texas. These are supposed to be of organic origin, and derived from the remains of animals or plants. They may be obtained also by distillation of shales of various kinds.

(*g*) Recently fuel-blocks, or **briquettes**, have come into use. They usually consist of fine coal or other combustible material, cemented together by pitch. Sawdust, spent tan, and peat have been used, but have not proved so successful as coal.

The following analyses of fuels will enable a comparison to be made as to their constitution and heat producing effects.

	C.	H.	O. & N.	Ash.	Heat evolved by complete combustion of 1 gram. of each measured in calories (gram.-degrees).
1. Anthracite (S. Wales)	91	4·3	3·2	1·5	8,000.
2. Hard coal	75·58	5·5	9·46	5·46	7,500 to 6,400 (varies).
3. Lignite (woody coal)	65·3	6·6	25·3	2·1	4,500.
4. Peat	57·53	6·83	33·65	1·99	3,600.
5. Wood	40	4·8	33·6	1·6	2,900.
6. Petroleum	86·3	13·6	·1		11,400.

Note the decrease in the percentage of carbon from (1) to (5) in the above, and the increase in the proportion of gaseous substances, which is suggestive as to the method of formation of coal.

Heating Appliances.

The chief appliances for heating dwellings and other buildings are:—

1. Open grates.
2. Closed fires or stoves.
3. Gas fires or stoves.
4. Oil stoves.
5. Hot air apparatus.
6. Hot water pipes.
7. Steam pipes.

1. Open grates.

Of the various arrangements for the consumption of fuel, the most common in England is the open grate. An ordinary grate will burn about 8 lbs. of coal per hour. The heat produced by burning 1 lb. of coal should suffice (theoretically) to raise 4,800 cubic feet of air 10° F. in temperature.

With the open grate, however, so large an amount of the heated air passes up the chimney, that at least 80 per cent. of the heat produced is wasted.

To prevent this excessive waste, various improved grates have been introduced.

Some of the objects their inventors aimed at are:

(*a*) Increased radiation of the heat produced.
(*b*) Warming of the air entering the room by passing it over, through, or round the heating source.
(*c*) Decreasing the rate of combustion of the fuel.
(*d*) Decreasing the rate of flow of air up the chimney.

(*a*) Increased radiation is accomplished by (1) building the fireplace well into the room; (2) having it constructed of firebrick as much as possible; (3) having the back of the grate sloping over the fire to deflect the heat in the room. Doulton's grate is a good example of the fireclay grate.

(*b*) Dalton's grate is one which aims at warming the incoming air. The air enters a chamber at the back of the grate where it becomes warmed, and passing up a separate flue, it enters the room between the mantelpiece and the ceiling. Boyd's grate is similar in principle, but the air

enters the room immediately under the mantelpiece. (In these grates the incoming air should not be in contact with red-hot iron surfaces or carbon monoxide may be produced.) See fig. 41.

(*c*) To limit the rate of combustion the following arrangements are adopted: (1) the bottom of the grate is made solid and on a level with the floor, (2) the depth of the grate from front to back is decreased, so that combustion only takes place on the top and in the front.

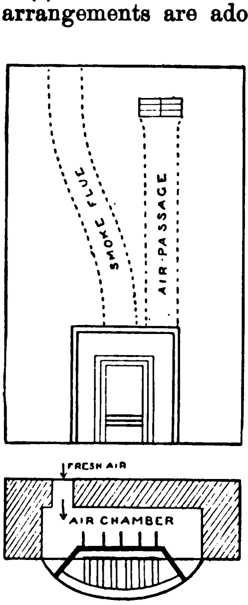


Fig. 41.—Plan and Elevation of Grate with Air-chamber behind it.

(*d*) The rate of efflux of the air up the chimney is lessened by narrowing the chimney, but care must be taken that it is not restricted too much, or the fireplace will not act so well as a ventilating agency.

In addition to the waste of fuel, open grates produce much dust and dirt. Their great advantages are (1) they have a cheerful appearance, (2) they are good ventilators.

2. **Closed fires or stoves.** These are generally constructed of cast-iron, sheet-iron, bricks, or tiles. As the flues leading from them are not restricted to a wall, the stove can be placed in the midle of the room, which will then be more uniformly heated than by an open fire at one side. The rate of combustion can be regulated better than in an open grate, because the fuel is enclosed from the air.

The *disadvantages* of *iron stoves* are :—

(1) They occasionally produce an unpleasant smell when the outer case becomes so hot as to burn the dust particles floating in the air.

(2) They increase the drying power of the air, thus causing an unpleasant sensation on the skin. This, however, is partially prevented by placing a vessel of water on the stove.

(3) They frequently cause headache, on account of the absence of ventilation and neglect of the use of water.

(4) They may produce carbon monoxide (which passes readily through red-hot cast-iron) owing to the imperfect combustion of fuel caused by the limited supply of oxygen. This is especially likely in closed coke stoves.

Some of the improved stoves have double casings, so that the incoming air may be warmed by passing between them in contact with the heated surface. Closed stoves are more frequently used for houses on the Continent and in America than in England.

A great disadvantage is that they do not assist in the ventilation of the room unless special arrangements are made.

3. Gas fires or stoves.

Some of the *advantages* of these are :—

(1) They are clean ;
(2) They are convenient and save time in lighting ;
(3) They can be easily regulated ;
(4) They are more economical than a coal fire, if only required occasionally.

The *disadvantages* are :—

(1) They are expensive as a rule—the cost varies with the cost of gas.
(2) They vitiate the air of a room, unless a flue is provided to carry off the products of combustion.

The chief varieties are :—

(1) *Refractory fuel stoves*, in which fireballs consisting of fire-clay and asbestos are rendered incandescent by the heat from a row of Bunsen burners and radiate their heat into the room.

(2) *Reflector* stoves, which have a gas flame with a reflector behind. These produce little heat and although bright and cheerful-looking are seldom provided with a flue.

(3) *Condensing* stoves, in which the products of combustion are passed into water and partly condensed. (The CO_2, however, is not condensed.)

(4) *Calorigen* stoves, which provide for the heating of the incoming air. These are the most efficient of the gas fires. George's, Fletcher's, and Bond's are three examples. In *George's* a coil of iron tubing passes through the body of the stove, one end communicating with the open air, and the other opens on the top of the stove, into the room. The heat produced by the combustion of the gas not only heats the outer case but also heats the air in the tube which rises into the room. *Bond's Euthermic Stove* shown in fig. 42 is one of the best. Instead of a coiled tube there is a cylinder which occupies a large portion of the interior of the stove. This communicates with the outer air and the room, in addition there are air inlets to the burners at the base, which serve as a ventilator by withdrawing air from the room and causing it to pass along the flue into the chimney.

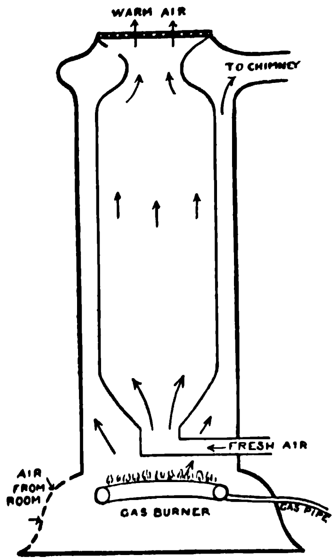


Fig. 42.—VENTILATING STOVE (Bond's).

4. Oil Stoves.

These are frequently used in country places, where gas is not in use. They are convenient but are not always provided with flues to carry off the products of combustion. They should have some kind of a radiator fitted over them to deflect the heated air which otherwise may rise direct to

the ceiling. The heat-producing power of petroleum is greater than that of an equal weight of coal (see table p. 160), but being in a liquid form it requires special arrangements for its combustion, and is not likely to supersede coal.

5. **Heating by means of hot air.**

In large buildings it is not so satisfactory a method of heating to have a fire in each of the rooms, for a large amount of work is entailed in attending to these numerous fires. To obviate this, air is heated in one part of the building and is allowed to pass along flues to the various rooms required. The air may be propelled by means of fans.

The arrangements for heating the air are either

(*a*) The heated products of combustion from the furnace are passed along a series of flues, while the air which enters from the outside circulates around them and becomes warmed; *or*,

(*b*) The air passes along flues which are surrounded by the flame and the heated products of combustion.

One very successful form of heating large buildings is in use in the Free Trade Hall, and in the Royal Exchange, Manchester.

Here a stove is fixed in a small chamber in the basement so that the walls form a casing for it. Fresh air enters this chamber from the outside, and after being in contact with the large heating surface of the stove, it is conducted along flues leading to various parts of the buildings.

To get a maximum heating surface, without increasing the fire, the stove has hollow projections from the sides. These are called convolutions, and the stove is called a *convoluted stove*. Fire-clay slabs are placed within as a kind of false covering to deflect the flame and heated products of combustion into these convolutions. Fig. 43 shows one of these stoves with 10 convolutions or projections, part of the wall is removed to show the brickwork casing or air-chamber which surrounds it when in use. The cold air passages are shown and the flues to conduct the hot air to

the building. The products of combustion pass along the smoke-pipe into a chimney and not along the hot-air flues. A comparison of this with fig. 43A will show the method of heating a large building such as a church, or public hall. Although more especially suited for large buildings

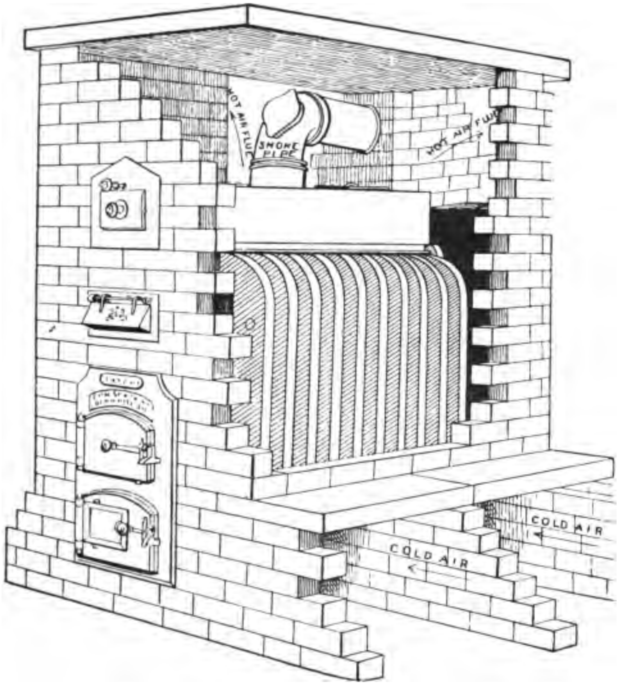


Fig. 43.—CONVOLUTED STOVE IN POSITION.

the system may be adapted to the heating of a house as shown in fig. 43B. The late Sir Isaac Holden had his private Turkish bath heated by a stove of this kind.

6. Hot-Water Pipes.

In heating buildings by means of hot water, use is made of the principles of convection (see page 158).

There are two systems of hot-water pipes :—

(*a*) Low pressure; (*b*) High pressure.

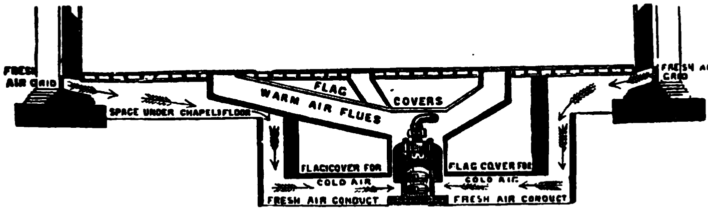


Fig. 43A.—Convoluted Stove to warm a Church.

(*a*) **Low Pressure System.**

Water is heated in a boiler having a pipe leading upwards from the top to various parts of the building, branching as required. The heated water flows along this system of pipes, which finally conducts the water back to

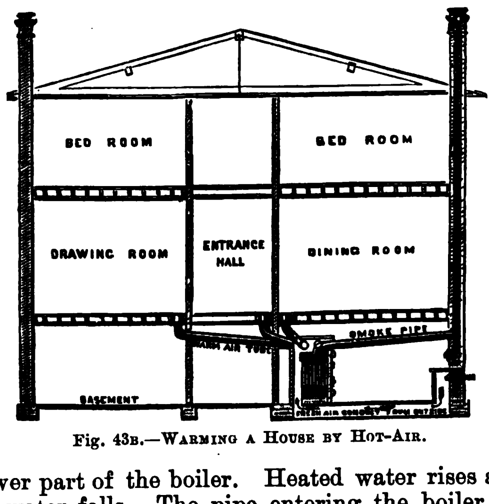


Fig. 43B.—Warming a House by Hot-Air.

the lower part of the boiler. Heated water rises and the cooled water falls. The pipe entering the boiler is connected with a cistern, which makes good any leakage or

waste through evaporation, and the highest point of the pipes is provided with a valve, to allow the air and vapour to escape.

The water being under the ordinary pressure of the atmosphere, and not allowed to boil, its temperature does not exceed 212° F., and the vapour pressure within the pipes is always below that of the atmosphere.

(*b*) High Pressure System.

The boiling point of a liquid is that temperature at which the pressure of its vapour is equal to the pressure it supports.

When heat is applied to a liquid from below, the vapour pressure increases, and when this becomes equal to the superincumbent pressure ebullition sets in, and the vapour escapes, or the liquid boils. If the pressure is small, the temperature of the water will be lower when boiling, than if the pressure is greater. At sea-level water boils at 212° F., but as we ascend a mountain we find that the pressure diminishes and the boiling point is lowered.

If the water be heated in a *closed* vessel as in the boiler of a locomotive engine, the steam first formed, being unable to escape, increases the pressure on the water, and additional steam cannot form until the water acquires a a higher temperature, so the increased pressure raises the boiling-point.

The annexed table gives the boiling-point of water at different pressures :—

Pressure (in Atmospheres).	Boiling Point.
1	212° F.
1·4	230° F.
1·96	248° F.
2·67	266° F.
4·7	302° F.
9·9	356° F.
15·4	392° F.
27·5	446° F.

In the **high pressure** system of heating we have pipes arranged to form a complete circuit, and these are *not* open to the air so that the temperature of the contained water may rise above 212°F.

A coil of piping is arranged in the furnace, and the pipes connected with this pass through the rooms to be heated and back to the furnace. At the highest part of the circuit a wider pipe is inserted, and this is not completely filled with water but contains a little air. The steam which is formed accumulates in this expansion pipe, and increases the pressure on the water.

COMPARISON OF HIGH PRESSURE AND LOW PRESSURE SYSTEMS.

High Pressure.	*Low Pressure.*
1. Stronger pipes required.	1. Pipes not so strong.
2. Owing to higher temperature of water a less heating surface is required. (Pipes $\frac{7}{8}''$ internal diameter frequently used.)	2. Pipes three or four inches in diameter required to provide a larger surface.
3. Only one row of pipes round a room is requisite.	3. Two rows of pipes generally required.
4. The temperature is frequently about 300°F., but it is apt to vary at different parts of the pipes, and very rapidly diminishes if the fire gets low for a short time.	4. Temperature always below 212°F., and owing to the larger volume of water in circulation it does not fluctuate so much as in the other system.
5. The pipes are more apt to overheat the air.	
6. The temperature is regulated by fixing the proportion of the circuit which is in the furnace. For dwelling houses we may have $\frac{1}{12}$ of the piping in the furnace; for a disinfecting chamber we require a higher temperature, and may have a larger proportion ($\frac{1}{4}$ or $\frac{1}{6}$).	

7. Steam pipes.

Steam heats more than an equal weight of water, because the steam gives up its latent heat when

condensed, in addition to the heat it gives off in cooling. If water at 212° F. be changed into steam at 212° F. heat is required to give the molecules sufficient energy to overcome the cohesion they possess as a liquid. On condensing the vapour, this amount of heat is given up again. This fact is made use of in heating rooms by steam. Steam passes along pipes about 1½ inches in diameter to the place to be heated. Here it enters pipes about 6 inches diameter where it condenses and the heat given up warms the air near the pipes, and also the water produced gives off heat. Arrangements have to be made for this water to flow back to the boiler, and generally another set of pipes is employed. This system may be used economically where steam is produced in large quantities, as in factories where it is used as a motive power. If the rooms to be heated are some distance from the boiler, the pipes are enveloped in felt, or some other bad conductor of heat, to prevent loss of heat during transit.

The temperature can be regulated by varying the pressure of the steam.

Steam may also be used to heat water, to circulate at a low pressure. Water in the boiler can be heated by having a coil of steam piping passing through it, instead of by means of a furnace, as is usually done in the low pressure system.

Warming incoming air.

If hot-water or steam pipes are employed *without providing for a good supply of fresh air* the results are not satisfactory. When the incoming air is heated, the best results are obtained. This may be done by using **Radiators** as part of the circuit for the water or steam, and having the passages between the heating surfaces connected with the open air (see fig. 44).

Cooling air.

In the tropics, it may be necessary to cool the air which enters the rooms; or it may be cooled for a refrigerating chamber.

To cool air use is made of the principles underlying the following facts :—

(*a*) If a liquid be changed into vapour heat is required. This is taken from surrounding objects, which become cooler, unless additional heat be supplied.

(*b*) If compressed air be allowed to expand, it is cooled.

To utilise the first, water or wet cloths are placed near the inlets. The incoming air in passing over these, gives up some of its heat and assists in the evaporation of the water; it then enters in a cooler condition.

The second is the principle generally adopted for refrigerating chambers. Air is compressed in vessels by means of a powerful air-pump, the temperature being thereby raised. The compressed air is cooled to the temperature of the atmosphere by allowing cold water to circulate through pipes in the air-vessels. When this cooled air is allowed to escape into a larger chamber where it will be at a lower pressure, heat is required to expand it, and this is taken from surrounding objects which are thus cooled. If a piece of meat is in this expanding air, heat is taken from the meat, and the juices may become congealed or frozen.

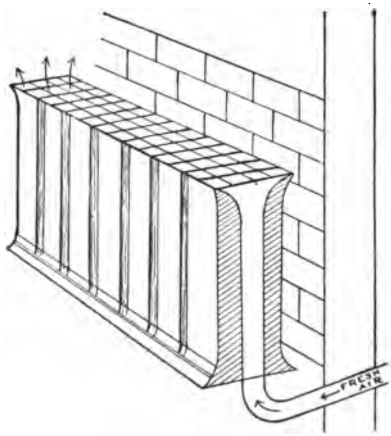


Fig. 44.—Radiator arranged to warm incoming Air.

On board ships engaged in carrying frozen meat from the Antipodes, the air is compressed and cooled, as above; then greatly cooled by passing into expansion cylinders. From these a current of air, at a temperature below the

freezing point of water, is conducted into the refrigerating chambers, where the merchandise is stored.

Comparison of the various systems of heating.

In 1889, Dr. Carnelley issued a *Report on the Cost and Efficiency of the Heating and Ventilation of Schools* for the use and by the request of the School Board of Dundee (see Chapter II.). The following summary is given (by special permission) from this report, which was founded on particulars concerning over 300 schools in various parts of Great Britain (150 personally examined).

Open Fires.

Advantages.

(1) More cheerful.
(2) First cost much less than hot-pipe systems.
(3) Keeps air fresher than hot pipes, owing to draught up chimney.
(4) So far as the Dundee schools are concerned, the temperature in the open fire schools was higher than those heated by other systems.
(5) The rooms of these schools will probably need painting less frequently than those heated by other systems.

Disadvantages.

(1) Greater labour in service.
(2) Slightly greater annual cost than stoves or steam-pipes or large hot-water pipes.
(3) Unequal distribution of heat.
(4) Air more highly charged with micro-organisms.

Stoves.

Advantages.

(1) Smallest first cost.
(2) Least annual cost.
(3) Probably more effective heaters than open fires.

Disadvantages.

(1) Greater labour in service.
(2) Require more attention than open fires.
(3) More liable to smoke than open fires.
(4) More liable to get out of repair than open fires,

Hot Pipes.

Advantages.

(1) Less labour in service than either open fires or stoves.
(2) The class is not disturbed as in the case of mending open fires and stoves.
(3) More equal distribution of heat.
(4) Air less charged with micro-organisms than when open fires are used.
(5) On the whole the annual cost is probably ***slightly*** less than with open fires, but more than with stoves.

Disadvantages.

(1) Not so cheerful as open fires.
(2) First cost much more than in the case of open fires or stoves.
(3) Air not so fresh as with open fires.

Comparison of Hot-pipe Schools.

(1) Small high-pressure pipes are cheaper in first cost than large low-pressure pipes.
(2) In those schools examined the air was better in rooms heated by small high-pressure pipes than in those heated by large low-pressure pipes.
(3) It takes longer to get up the heat with large than with small pipes.
(4) Small pipes are less obtrusive in rooms.

Bath Supply.

(1) One of the earliest forms of hot-water supply systems for house use, is the **worm-boiler system.** A boiler is placed at the side of or behind the kitchen fire, and is supplied from a small cistern near. Water is drawn from this for use in the kitchen. A long pipe which passes from a cistern in the upper part of the house has several coils in this boiler. The other end of the pipe passes up to the higher cistern and opens over it. Branch pipes fitted with taps enable water to be drawn from this pipe for sinks or baths.

The water in the coil becomes heated and rises up the pipe while cold water flows down the other part. This system is safe if the kitchen boiler be kept supplied, for even if the water in the pipe freezes, the heat which is applied to the water in the coil is not great enough to produce steam in the pipes, so there is no risk of an explosion.

With this system it is impossible to get a large supply of hot water, also when water is taken direct from the kitchen boiler cold water takes its place, and thus the heat for the pipes is variable. This system, however, is still met with.

(2) A common form of hot-water apparatus which is unsatisfactory and dangerous is one in which a small boiler at the back of the fire has a pipe bringing cold water to the bottom from a cistern, and a pipe passing from the higher part carrying water to various parts of the house, arrangements being made for drawing off water from this pipe which opens over the upper cistern. This system is fairly satisfactory while in good working order, but if both pipes become blocked with ice near the cistern, when a fire is lighted the water in the boiler cannot circulate along the pipes, steam is formed and an explosion follows. If only the cold-water pipe be blocked, the water in the cistern boils away, the boiler becomes red-hot, and when cold water suddenly rushes in, steam is rapidly formed and an explosion occurs.

(3) **The "Reservoir" hot-water system** is one of the best forms in use. In this, a metal reservoir is placed between the hot and cold supply, and the water heated in it by circulation from the boiler. The dangers in connection with the last system are minimised by having a larger volume of circulating hot water so that there is less danger of the water in the pipes being frozen, or of the water boiling away.

Fig. 45 shows diagramatically the arrangement of the boiler, reservoir, and cistern in this system.

To prevent accidents it is necessary to:—

(1) Disconnect from the mains and empty the pipes each night. (The water may be allowed to run off by means of a tap *at the lowest point* of the supply pipe.)

(2) To have a safety valve fitted to the boiler.

The common practice of turning the tap a little, allowing the water to run all night, is wasteful and is *illegal.*

(4) A "**Geyser.**" This is a convenient arrangement for supplying a bath with hot water and is being adopted in many parts where gas is available.

The **Geyser** consists of a hollow copper cylinder fitted over a number of gas-burners. Another cylinder covers

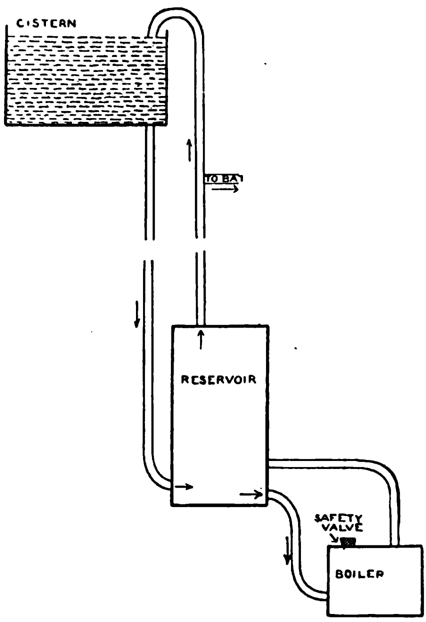


Fig. 45.—Reservoir Hot-water supply system.

this, allowing an inch or so of space between the two. Cold water flows from the tap over the heated inner cylinder, and into the bath beneath.

The advantages of this are :—(1) It is very convenient, as (*a*) it is possible to have a stream of hot water flowing into the bath in less than one minute after lighting the gas; (*b*) this flow of hot water may be continued indefinitely.

(2) There are no pipes required to connect the boiler with the bath. (3) There is no danger of the boiler bursting through frost or steam.

The disadvantages are :—

(1) The stream of water is so thin that it takes a long time to fill a bath.
(2) If the bathroom be large this thin stream of water may become chilled in very cold weather, and it is necessary to decrease the rate of flow still further so that it may be hotter when it leaves the geyser.

PRACTICAL WORK ON CHAPTER VII.

1. Heat water in a flask. Pour a little magenta solution on the water. Note the **convection currents** set up in the water, which may easily be traced by the movements of the dye as the heating is continued.
2. Place some powdered coal in the bowl of a churchwarden pipe. Close the top with clay and place the bowl of the pipe in the fire.

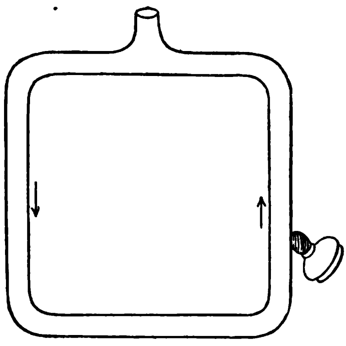


Fig. 46.—Apparatus to show Convection Currents.

After a time dark fumes will issue from the stem which are inflammable. This will illustrate the manufacture of **coal gas and coke.** The coke will be found in the bowl of the pipe.

3. The above experiment (2) may be performed in a small test tube. Place in some powdered coal ($\frac{1}{4}$ to $\frac{1}{3}$ full) and hold the tube and coal in

a Bunsen flame. The fumes are easily seen and can be lighted as they leave the mouth of the tube. In this case the tar produced will be seen on the sides of the test tube. The gas may be collected in a cylinder over water if required. This would illustrate the gas-holder or **gasometer.**

4. We can make a **comparison between coal and wood** if a few splinters of wood be heated in a similar tube. Tar is produced as with coal, but a much larger quantity of inflammable gas is produced from the wood than from an equal weight of coal. Charcoal is left behind in the test tube.

5. **To illustrate the convection currents in hot-water pipes.** Take a glass tube of the form shown in fig. 46, forming a rectangle 12 inches by 10 inches, fill with water to the neck. On applying heat to the water at one side, circulation will commence. If a little magenta solution be poured in at the neck the circulation will be rendered very apparent (but cannot be followed after the magenta has worked round to the neck).

6. **To show the latent heat of steam.** Place a weighed quantity of water in a vessel with a thermometer inserted. Boil water in a flask and pass the steam into this other vessel. After a time the water in the vessel is raised to 212° F. The heat which has raised this water to this temperature has come from the steam which has been condensed. *If steam has been passed until the water is at a temperature of* 212° F., the steam which has been condensed is not lowered in temperature for it now exists in the vessel *as water at* 212° F.; therefore the steam must have been able, when changing its state, to give up heat without having its own temperature lowered, *i.e.* it must have possessed some *latent* heat.

If, the vessel be weighed again, the additional weight gives the weight of the steam which has been condensed so that we can calculate how much heat a given mass of steam gives out when changing its state.

If a stream of hot air at 212° F., is passed through the water we shall have the water raised in temperature, but *the air which has passed through is cooled.* The air cannot give up heat without having its temperature lowered, while steam is able to do this.

CHAPTER VIII.

WATER-CLOSETS AND DRAINS.

House-pipes. The various pipes which carry away the refuse water from the house, whether from sinks, from slop-sinks, or from water-closets, are called *house-pipes.* the water flows from them into other channels which conduct it to a cesspool or sewer. **House drains** consist of the pipes connecting the house-pipes with the cesspool or sewer.

The legal definition of a drain according to the Public Health Act, 1875:

"*Drain* means any drain of and used for *the drainage of one building only*, or premises within the same curtilage, and made merely for communicating therefrom with a cesspool or like receptacle for drainage, or with a sewer into which the drainage of two or more buildings or premises occupied by different persons is conveyed."

According to this act a sewer is a drain receiving the drainage of two or more buildings, while under the Public Health Act Amendments Act, 1890, the combined drain is only called a *sewer* if the houses *belong to one owner*. (The reason for such distinctions is that *Sewers* are repaired by the Sanitary Authority, and *drains* are repairable at the owner's expense.)

House-pipes may be made of iron, lead, zinc, or earthenware. Iron pipes are the best. They should always be placed so as to be easily inspected, otherwise there is danger in case of leakage. No house-pipe (except the soil-pipe from the W.C.) should enter the drain directly, but should open over a channel leading to a gully-trap which connects with the drain, and the opening should be at least 18 *inches from the gully*. The reason why the pipes should not open *over* the gully is that the danger of sewer-gas passing up the house-pipes may be removed.

Sinks.

These are the ordinary kitchen or scullery sinks, and may be made of glazed stoneware, or of wood lined with copper or lead. They should *not* be made of porous stone. If lead or copper is used, it should not be too thin, as the extra cost of a thick metal is very small for an ordinary sink and is easily saved in repairs. Copper is brighter and has a cleaner appearance than lead. *Glazed stoneware* sinks are the best, but they are rather destructive to glass and crockery.

The bottom of the sink should slope to a grating, which should be fitted in a cup-shaped depression in which a plug may be inserted for flushing purposes. An overflow pipe should be provided, for use in case the supply-pipe is left running when the plug is in. The waste-pipe must be of *the full width of the grating* where it leaves the sink, but may taper to 1½ inches from that point. Just below the sink it should be provided with a siphon-trap having a 3 inch water-seal, and fitted with a screw-cap for cleaning. The pipe should open outside, in the air, *not* into a soil-pipe. The waste-pipe and the overflow pipe should each be 1½ inches in diameter throughout.

Slop-sinks.

These are used for pouring waste water down, and are especially useful in the absence of a W.C. See fig. 47, page 180, which shows a recent form of slop-sink. They generally consist of a basin, either of enamelled iron or glazed earthenware, fitted up in a manner similar to a water-closet, except that the waste-pipe need not be so wide as a soil-pipe 2 inches to 2½ inches being sufficient. A grating is necessary to prevent cleaning utensils or materials (soap, etc.) from passing down the waste-pipe. The slop-sink should be provided with a flushing cistern like that of a water-closet. In many houses there is no special slop-sink, and the water-closet is used instead. There are no objections to this custom if reasonable care be taken; the lid should be hinged and should always be raised before the slop-pail is emptied into the closet so that no nuisance will arise.

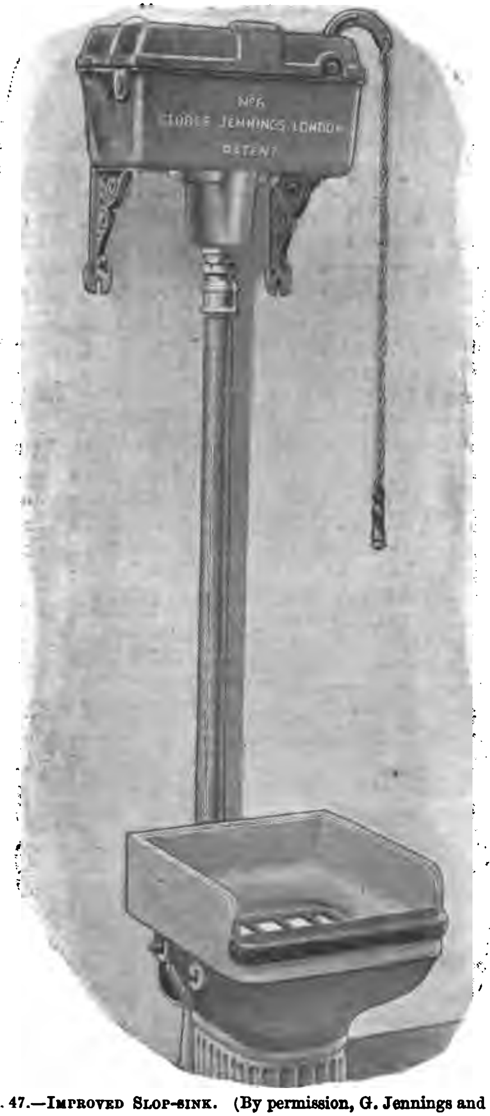


Fig. 47.—Improved Slop-sink. (By permission, G. Jennings and Co.)

Baths.

The bathroom should be placed near the outside of the house so that waste water can readily be carried away. It is becoming customary to place a bath and a water-closet in the same room. The objections to this are: (1) the W.C. is unavailable for other members of the household when the bath is used, and (2) the person taking a bath breathes impure air, if there is anything wrong with the W.C. fittings. Bathrooms should be well-ventilated. The floors should be covered with some impervious material (oil-cloth or linoleum will prove satisfactory), and have a cork mat beside the bath. The walls should also have a covering impervious to moisture or the steam from a hot bath when condensed will be absorbed.

The waste-pipe from the bath should be completely disconnected from the drains, in the same manner as sink-pipes, that is (*a*) with a siphon-trap near the bath, and (*b*) the waste-pipe either joining another (which opens in the air) or itself ending in the open air. An overflow pipe also should be provided. In some cases, a safe or tray is fixed under the bath, as a precaution against possible accidents, such as overflow pipe being blocked or a pipe bursting.

The waste-pipes from lavatory basins should be fixed with the same precautions as in the case of baths or sinks. If the waste-pipes from several basins enter into a common one, each basin should be separately trapped, and have an air-pipe to prevent siphonage.

Water-Closets.

These are used to get rid of excreta by means of a flush of water, which carries it along a soil-pipe and drain into a sewer.

An arrangement is required which will :—

(1) Prevent any sewer-gas passing into the house;
(2) Not become foul itself and cause a bad smell;
(3) Produce a good flush of water, when required, without waste.

The chief kinds of water-closets are—(1) the pan, (2) the long hopper, (3) the valve, (4) the plug, (5) the short hopper, (6) the wash-out, and (7) the wash-down closet.

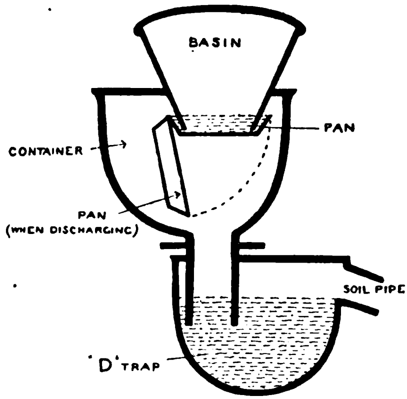


Fig. 48.—Pan Closet.

(1) **Pan Closet.** This is very unsatisfactory in various ways. It consists of a conical basin fixed with a cast-iron vessel called a *container*. The outlet of the basin is into a movable pan of tinned copper, containing a little water, which is supposed to act as a water-seal and prevent foul air escaping.

Each time it is used the hinged pan is tilted down, and discharges its contents into the container. The sides of the container are inaccessible for cleaning and the upper portions are out of reach of the flushing action of the pan, and thus they gradually become coated with a filthy deposit. When the pan is swinging down there is no longer a water-seal, and a gust of foul air rises from the container each time it is used.

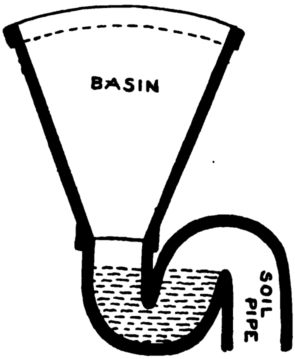


Fig. 49.—Long Hopper Closet.

If the water dries up or the pan becomes foul a bad smell is caused. To make matters worse, the container frequently opens into a "D"

shaped vessel, which is also liable to become a gathering place for filth.

The Model Byelaws issued by the Local Government Board for the guidance of Sanitary Authorities prohibit the fixing of a "Container" or "D" trap to any new water-closet.

(2) **The Long Hopper Closet.** This consists of a deep conical basin ending in an "S" shaped pipe, in which

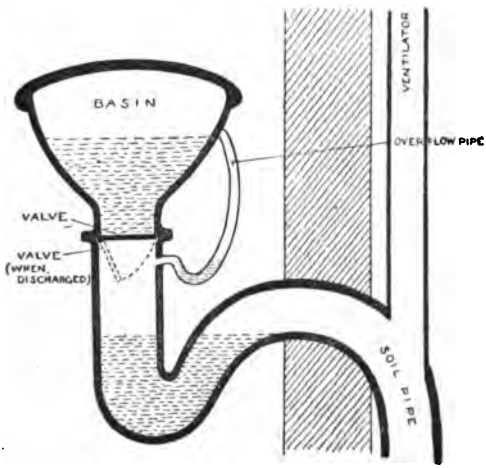


Fig. 50.—Valve Closet.

water stands. There is no container, the excreta falling straight into the trap and being carried over the projection with the flush of water. Owing, however, to the shape of the basin, the sides are apt to become fouled to a great extent and the flow of water fails to cleanse them. This is a cheap closet, but it is not satisfactory for slum property, or common closets.

(3) **The Valve Closet.** This closet is noiseless in action, but is very expensive and not so efficient as some of the more recent kinds. Instead of a container and a pan it

has a tight-fitting valve, which when released, allows the contents of the basin to fall directly into the siphon-trap and pass into the soil pipe.

Fig. 51 shows an improved patent valve closet which differs a little from the one in fig. 50.

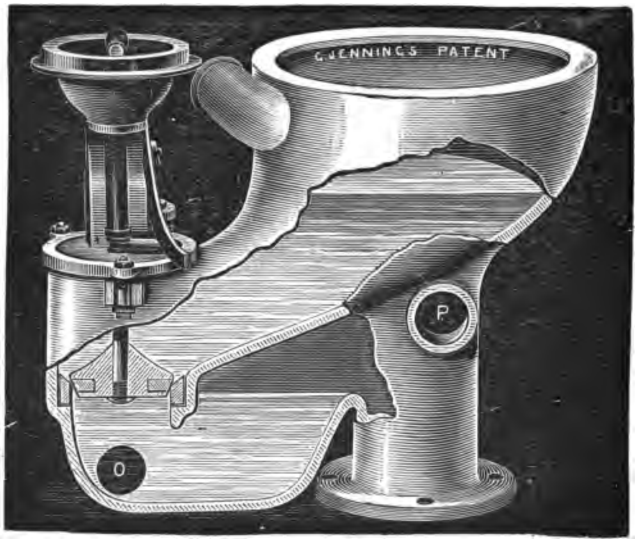


Fig. 51.—IMPROVED VALVE CLOSET. (By permission.)

The objections to the valve closet are :—

(1) Unless the valve is water-tight, the water trickles down and leaves the basin empty.

(2) If, by any chance, the water in the bend of the overflow pipe disappears, foul air escapes into the house.

(4) **The Short Hopper Closet.** This is generally made of stoneware and is a great improvement on the Long

Hopper. It has a smaller surface to be flushed and is cleaner. The basin fits into a stoneware trap in which the excreta falls direct.

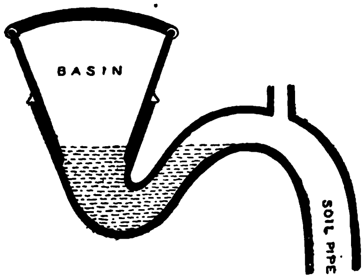


Fig. 52.—SHORT HOPPER CLOSET.

There is occasionally a difficulty in joining the *stoneware* trap to a *metal* pipe, and special joints are required. India-rubber is sometimes placed between the flanges of the stoneware and the lead pipe, but it is apt to decay. There are some patent joints (*e.g.* Doulton's, and Twyford's) in which a lead pipe is soldered to the stoneware by a special process, before it is fixed, so that the soil-pipe has only to be connected to lead, which can be made water-tight very easily.

(5) **The Wash-out Closet.**

This is constructed of stoneware, and differs from the short hopper, as follows:—

(1) The basin and trap are constructed in one piece.

(2) The basin is shaped so as to form a shallow container into which the excreta falls.

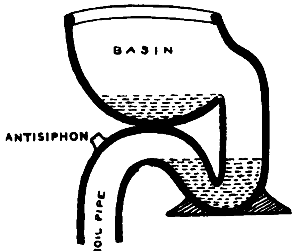


Fig. 53.—WASH-OUT CLOSET.

The flush of water carries it over the ledge and into the siphon-trap below. The layer of water is placed in the basin to prevent it being fouled by excreta.

The advantages are :—

(1) It is cheap.
(2) It has no mechanical parts to get out of order.
(3) It is open to inspection.
(4) It is not necessary to enclose it in a case.

The disadvantages are :—

(1) The water in the basin is not sufficient to cover the excreta and is apt to splash.
(2) The splashing causes portions of the basin to be fouled in a position out of reach for cleansing. This may cause the glaze to crack, thus rendering it absorbent instead of impervious.
(3) The basin interrupts the downward flush, so that the water loses the energy gained by the direct fall from the cistern and only partly clears the trap which may become fouled by deposits on the sides and give rise to bad smells.

(6) **The Wash-down Closet.**

This is one of the best water-closets in use. It differs

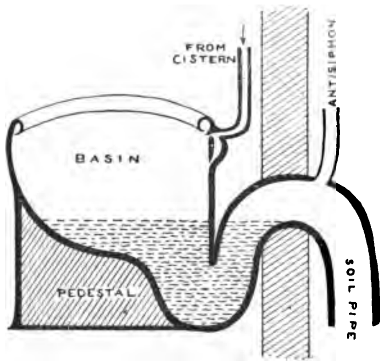


Fig. 54.—Wash-down Closet.

from the short hopper in that the basin and trap are in one piece.

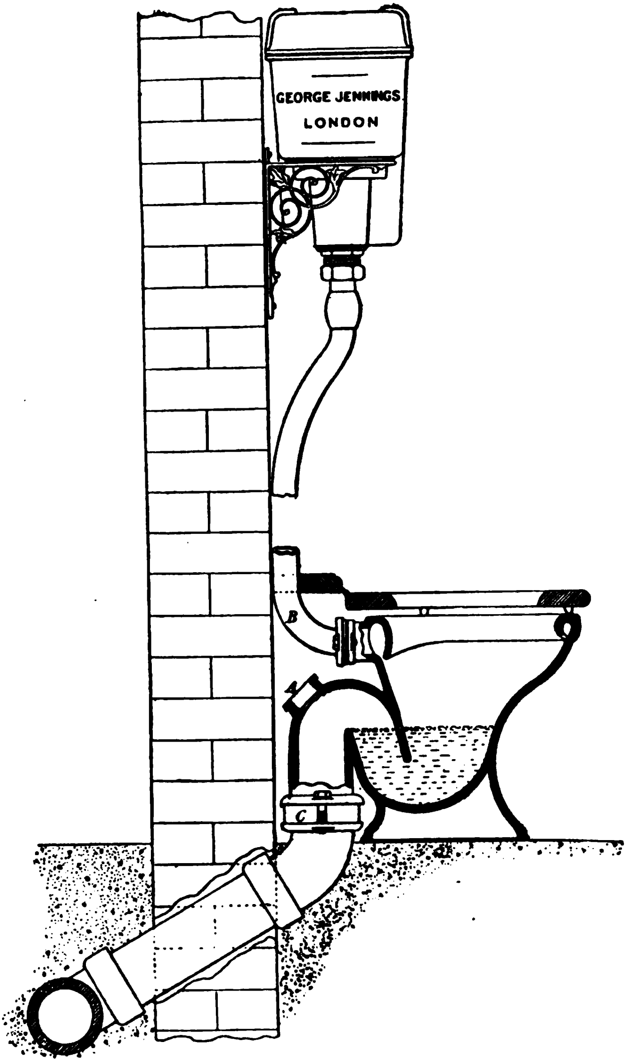


Fig. 54A.—Jenning's Deep-seal Wash-down Closet.
(By permission of G. Jennings & Co.)

There should be sufficient water in the basin to prevent the excreta fouling the sides. It is then not open to the objection of splashing as in the wash-out closet, nor does the flush of water lose its force owing to an intercepting container.

(7) The Self-flushing Closet.

There are various contrivances in existence to render the flushing of the closet independent of the users. One of the old forms is shown in fig. 55, in which weights attached to the back of the seat cause this to tilt up when it is released. At the same time a lever arrangement ensures a flush. An advantage of a self-flushing arrangement is that if used as a urinal or slop-sink the seat cannot be fouled through carelessness.

"Closet of the Century."

A recently introduced and good type of water-closet is the improved "Closet of the Century," a figure of which is reproduced by permission of the inventors.

The service-pipe from the cistern has two connections to the closet—one leading into the basin in the usual manner, the other leading into the top of the long leg of a siphon-pipe. The flush from the cistern is thereby divided into two streams—one flushes the basin, the other rushes down the "leg" *D*, expels the air through the puff pipe *E*, starts the siphonic action, and empties the basin, which is refilled with clean water by a simple after-flush arrangement in the cistern.

Fig. 56A shows this fitted with a water waste-preventing cistern, and joining the drain beneath the ground level.

Pipe *A* is taken up to the level of the cistern and left open to admit air to the siphon-leg *D*, thus preventing siphonage when slops are poured in the basin *C*. The puff pipe *E* passes through the wall and is left open as shown.

Flushing cisterns or *water waste-preventers*. To prevent the flushing of closets from being imperfect though carelessness, many plans have been devised for ensuring that once the flow of water is started it will continue until a given volume has been discharged. A good arrangement

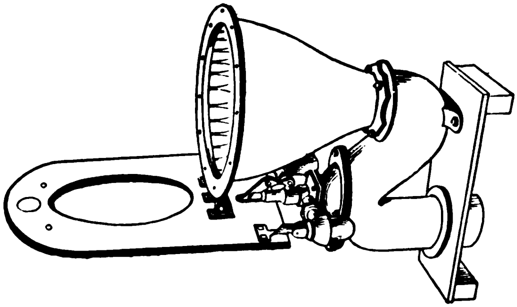


Fig. 55.—Self-flushing Closet (Old Form).
(By permission of G. Jennings & Co.)

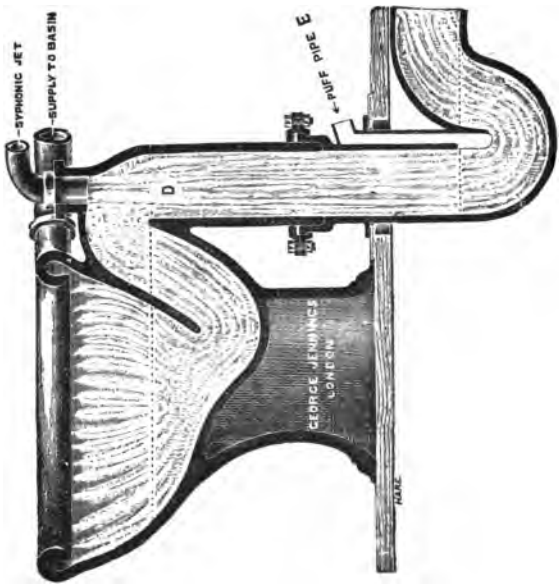


Fig. 56.—"Closet of the Century." (By permission of G. Jennings & Co.)

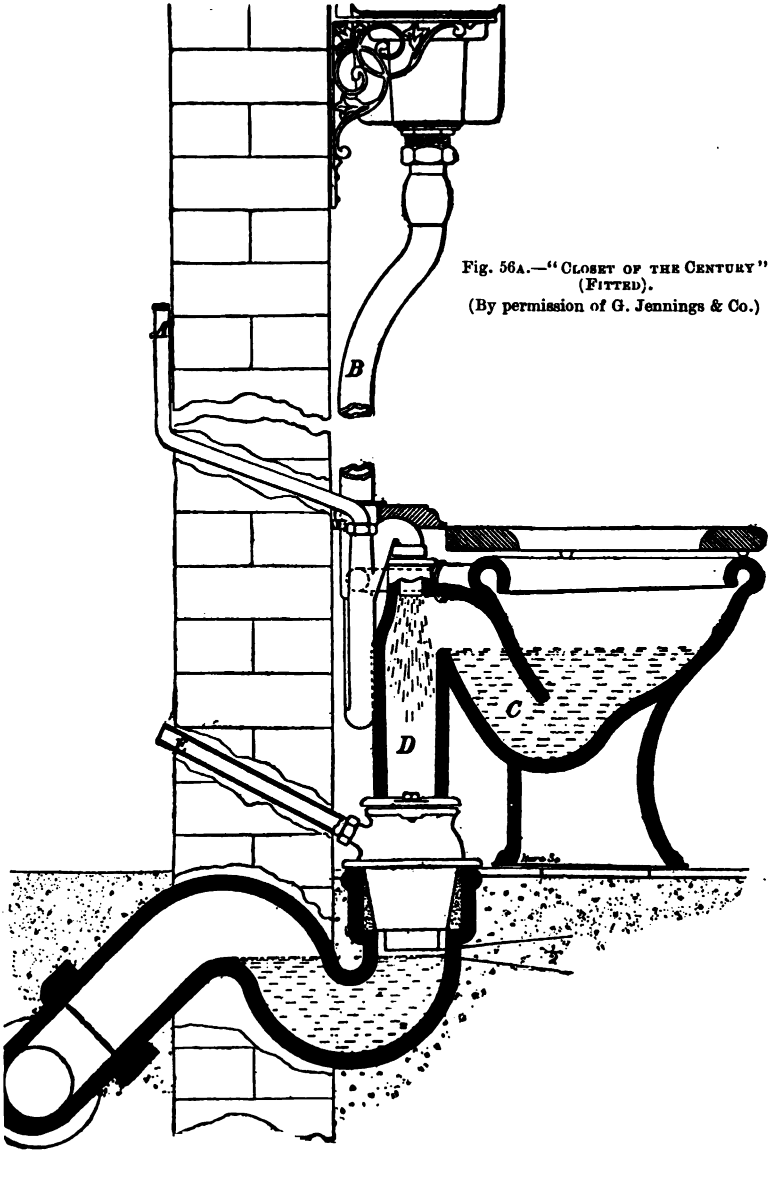


Fig. 56A.—"Closet of the Century" (Fitted).
(By permission of G. Jennings & Co.)

is shown in fig. 57. When the plug is removed, water rushes down the pipe and sets the siphon into action; then, even if the plug is replaced, the pressure of the air keeps the water flowing down the siphon until the surface is lowered so much that air is admitted to the short end of the siphon-pipe. Sometimes an air-tube is fixed to the upper bend of the siphon. The volume of water to be discharged can then be regulated by varying the length of the tube. The shorter the tube, the less the volume which flows, as air is admitted sooner. A ball-tap is used for automatically refilling the cistern after discharge.

The cistern may be made of enamelled iron, or of wood lined with lead.

The quantity of water required for flushing a closet is 3 gallons, and to prevent waste it should not exceed 3½ gallons. The flushing cistern should be placed 5 or 6 feet above the basin, and in no case less than 4 feet. The

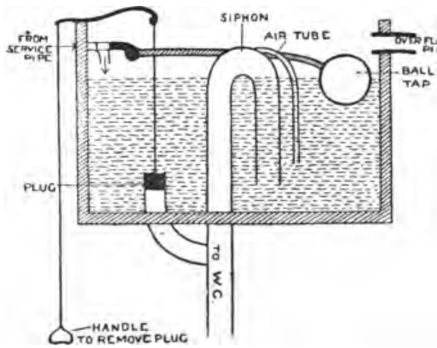


Fig. 57.—FLUSHING CISTERN OR WATER WASTE-PREVENTER.

pipe which carries the water to the W.C. should be 1¼ to 1½ inches in diameter.

Soil-pipes. The pipes which carry excreta and other refuse from water-closets to drains are called *soil-pipes.* As far as possible they should be placed outside the house

and not exposed to the action of the sun's rays, or they may become bent, or the joints may open owing to expansion. A soil-pipe may be made of lead or iron. *Drawn lead* pipes are the best kind, but are expensive; *seamed lead* pipes should not be used. *Iron pipes* are cheap, but often have a rough surface, which may corrode. If iron pipes are used they should be coated by Angus Smith's method, as for water mains. The soil-pipe should be 3½ inches to 4 inches in diameter. If it be wider there is (*a*) a larger surface to be flushed, (*b*) a greater area on which deposit may take place, (*c*) extra cost without extra advantage.

The joints of iron pipes should be caulked with molten lead, but, owing to the difficulty in making a perfect joint, iron should never be used for pipes within the house. *Drawn lead* pipes should be uniform in thickness, and should weigh from 7 to 8 lbs. per ft. A soil-pipe should always be ventilated by being carried up full bore above the eaves, and should terminate away from all chimneys and windows. There should be as few bends as possible in the ventilator. If it is necessary to deviate from a straight line, rounded curves, instead of right angle bends should be employed.

Trough Closets. These consist of a long metal or earthenware trough placed under a series of closets built side by side. The seats are all arranged over the trough which is partly filled with water and into which the excreta from each falls. The bottom slopes towards the drain, and at the end a ridge is placed to keep the water in the trough. It has been described as an elongated wash-out closet, with a number of separate seats. The upper end is connected with a flushing tank, which may be automatic, or only used when the attendant cleans them out daily. The volume of water required in the cistern depends upon the number of closets connected with the trough, the contents of which are carried by the flush through a trap into the drain. A few bars may be fixed over the opening to prevent unsuitable articles passing into the trap and blocking it, but these should be arranged so that all ordinary matter may pass between.

The advantages are :—

(1) They are well adapted for schools, factories, or artizans' dwellings.
(2) They are not so liable to get out of order with rough usage.

A large drain and a plentiful supply of water are required to carry the contents away.

The disadvantages are :—

(1) They require a very lavish supply of water.
(2) They are expensive to fit up at first.

Slop-closets. These are used where it is necessary to economise water, and the waste water of the household is

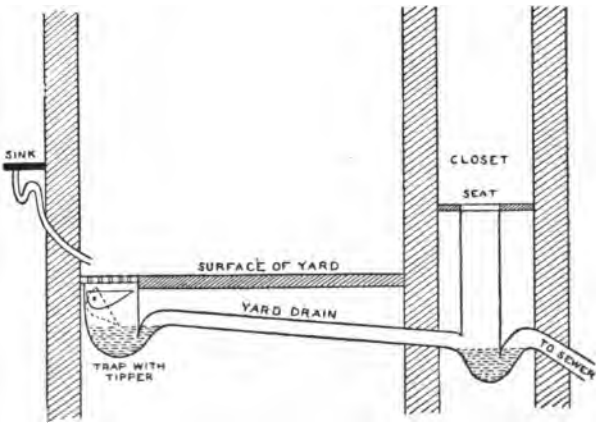


Fig. 58.—Slop Closet.

used for flushing. There are two classes of slop-closets :—

(1) Those in which the water runs directly to the closet.
(2) Those in which a certain volume of water is collected and discharged with sudden force.

The figure of a slop-closet shows one arrangement. The water from a sink falls through a grating, beneath which a tipper is placed. Fig. 58A shows a tipper. It consists

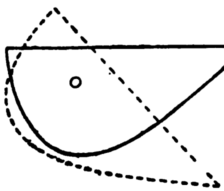


Fig. 58A.—TIPPER FOR SLOP-CLOSET.

of a metal vessel so shaped and pivoted that when it is filled it overbalances, and the whole of its contents are discharged. In some cases the water flows into a cistern with a siphon arrangement, so that when the water reaches a certain height the contents are siphoned off. Owing, however, to the greasy nature of slop-water, this is not so satisfactory as the Tipper system. Sometimes (as in Day's closet) the tipper is used as the receiver for the excreta and for sink water; it is placed immediately under the seat, and the sink water carried to it by the drain. The tipper should hold about 3 gallons, but, if it receives water to flush two or three closets, it should hold 5 gallons.

Advantages of slop-closets:—

(1) There is not much danger of frost interfering with their working, as most of the pipes are placed at a sufficient depth.
(2) They are economical, as only waste water is used.
(3) There is a less quantity of sewage to be dealt with.

Disadvantages.

(1) They are not so clean as ordinary water-closets.
(2) The sewage is concentrated and requires special treatment, as it rapidly putrifies.
(3) The ventilation of drains is more complicated.

Drains.

Drains are required to carry waste water, excreta, etc., from the house-pipes to a sewer or cesspool as rapidly as possible.

Good Drains should :—

(1) Be smooth and permit a rapid flow of water;
(2) Be non-porous and well-jointed to prevent ground-water entering;
(3) Not allow sewage to escape and percolate the soil;
(4) Be disconnected by traps from the house and the sewer so that they will not act as channels to convey sewer-gas into the house.

Bad Drains. A drain is bad :—

(1) If it has sharp corners which prevent a rapid flow of water, or has a rough surface;
(2) If it is porous or has faulty joints;
(3) If the drain is always full through being laid in a water-logged soil;
(4) If the drain is uneven through subsidence of soft soil in which it is laid;
(5) If it fails to comply with any of the requirements of a good drain as shown above.

Construction and Ventilation of Drains.

The chief principles to be observed in constructing drains are :—

(1) The pipes should be of earthenware, perfectly joined with a smooth interior, well glazed, and free from flaws or cracks.
(2) The gradient should be 1 in 40 in 4-inch pipes, but short drains may have a fall of 1 in 10.
(3) The trench in which they are laid should not be dug out to a greater depth than is necessary, as this entails replacement of some of the soil, and there is a risk of subsidence, owing to the bed being insecure.

(4) They should be laid on a bed of *concrete*, 4 inches thick, unless the ground is naturally solid.
(5) They should not be laid under a house or near a well; if this, however, is unavoidable, they should be embedded in concrete.
(6) They should be as straight as circumstances will permit; if a bend is necessary, curved, and not straight pipes should be used.

The accompanying figures show the differences between a joint with two straight pipes and one with curved ones. The first forms angles which check the flow, and as one pipe does not fit into the other, an imperfect joint is produced which is liable to leak.

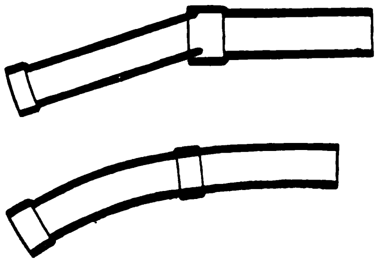


Fig. 59.—Joints, with Straight Pipes and Curved Pipes.

Branch drains should not join at right angles to the main drain, but a V-shaped pipe should be used as in fig. 60 below, instead of knocking a hole in the side for the branch drain to flow into.

If a branch drain enters at right angles, substances are splashed and become dry on the sides of the drain above the water line, and in time these produce an obstruction.

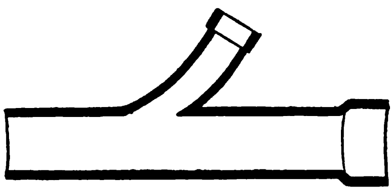


Fig. 60.—Junction Pipe.

Joints. To prevent water soaking into or sewage escaping from the drain, it is necessary to have good joints. The best Portland cement should be used. *Clay* is not satisfactory. A good method for ordinary drains is to steep some yarn in very fluid cement: this should be

well padded in the socket of the pipe, round the spigot end of the one which fits into it; and then complete the joint with stiffer cement.

Various patent joints have been introduced, which it may be necessary to use when pipes have to be made water-tight to be laid in a water-logged soil. Stanford's improved pipe joint is a good form. The tightness is

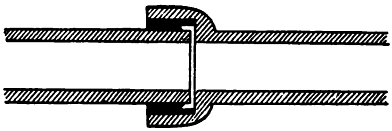


Fig. 61.—STANFORD'S PIPE JOINT.

obtained by casting upon the spigot, and in the socket of each pipe by means of moulds, rings of a durable material which, when put together, fit mechanically into each other. In laying these pipes the rings are first smeared with grease, and then the spigot of one is firmly inserted into the socket of the other. The composition on the spigot is convex in shape, and thus allows for slight movements to which the pipes may be subjected after laying, without causing the joint to leak.

Another good joint is **Hassall's** (fig. 62). In this two bands of bituminous material are cast on the two ends of each pipe so arranged that the space between the two

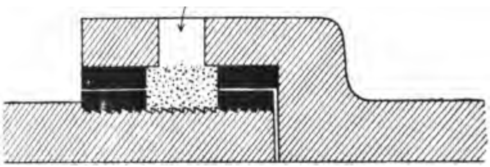


Fig. 62.—HASSALL'S PIPE JOINT. (This shows one side of pipe.)

bands forms an annular space. Two holes are arranged in the socket end, so that when the pipes are laid liquid cement may be poured in one to fill this space until it

overflows at the other. The joint is thus encircled by a band of cement in addition to the bituminous material. The patent joints are expensive, but where drains are to be permanent the extra cost is saved in repairs.

Care should be taken in making the junction of the soil-pipe and the drain satisfactory. The usual practice is to introduce the plain end of the soil pipe into the socket end of the drain and then cement the joint.

A better form of joint is shown in fig. 63. The soil-pipe is continued some distance in the pipe and has a lead

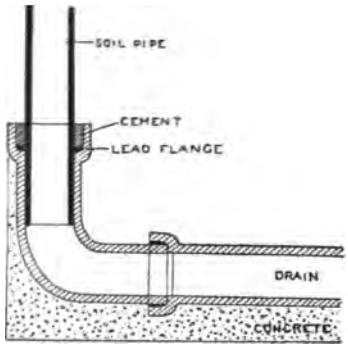


Fig. 63.—JUNCTION OF SOIL-PIPE WITH DRAIN.

flange which rests on the edge of the socket. The space above this is filled in with cement. *There should be no trap between the soil-pipe and the house-drain.*

Ventilation.

It is necessary to ventilate the soil-pipes and drains to prevent an accumulation of impurities which might pass into the house. The soil-pipe should be ventilated by being continued *full-bore* upwards to a height sufficient to prevent ascending air being carried in at a window or chimney. There should be as few bends as possible in this pipe. Sometimes a cowl is fixed on the top of the ventilator, but its advantage is doubtful.

The *drain* should be ventilated where it joins the sewer. Buchanan's disconnecting and ventilating drain trap is a good form to use.

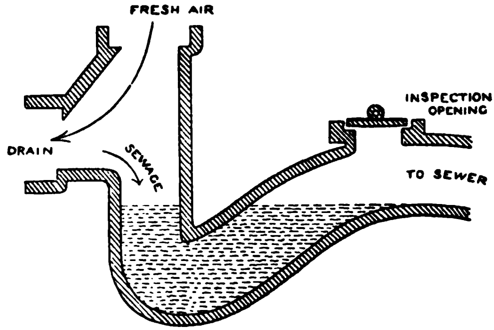


Fig. 64.—Buchanan's Disconnecting and Ventilating Trap.

The sewer-air is prevented by the water in the bend from gaining access to the drain, and fresh air enters from the opening above.

Another method is to place a manhole at the junction with an open grating. The drain should be continued along the floor of the manhole by half-pipes so that the sewage can be seen flowing, with a trap between it and the sewer.

Traps.

A *trap* is a contrivance which prevents the passage of sewer-air into a drain, or from house-pipes into a house.

This is done by the interposition of water between the inlet and the outlet.

There have been many forms of *bad traps* in the past, such as—

1. The mid-feather trap;
2. The "Bell" trap;
3. The "D" trap.

1. **The mid-feather trap** is also known as the dipstone or mason's trap. It consists of a rectangular brickwork box

into which water flows from the house-pipe or drain and then passes out on its way to the sewer. A slab of stone is built vertically into the walls to divide the upper part into two sections. This is arranged to dip into the water, as shown in the figure. The water which is left in the trap prevents gas passing the partition.

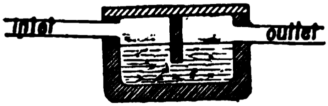


Fig. 65.—The Mid-Feather Trap.

Objections to its use :—

(1) The water in the trap may evaporate and sewer-gas will then pass under the vertical partition.
(2) The shape of the trap prevents it being cleaned, hence matter accumulates in it to the detriment of health.

2. **The bell trap** consists of a receptacle or box with a grating for the upper covering, and attached to this is a bell-shaped piece of iron which dips into the water. The outlet pipe opens under the bell as in the figure. Any gas from the sewer gathers in the bell without passing to the drain, for the bell dipping into the water prevents it. Bell traps are frequently used for sinks, but should be discarded.

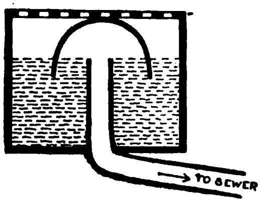


Fig. 66.—The Bell Trap.

Objections to its use :—

(1) The trap is valueless whenever the grating is raised, and this with the attached bell is liable to be left off.
(2) Water may evaporate as in the dipstone trap.
(3) The shape of the box favours accumulation of filth.

3. **The "D" Trap** consists of a vessel shaped like the letter D (hence its name), and was formerly much used for water-closets, see fig. 48 of pan-closet.

Objections:—

(*a*) Too much surface is exposed to be coated with filth.
(*b*) There are too many angles and bands, which prevent it being self cleansing.
(*c*) The accumulation of filth thus caused gives rise to bad smells.

Two *more recent traps* are:—

1. The Siphon Trap;
2. The Gully Trap.

1. **The Siphon Trap** is a very useful kind, and in its simplest form consists of a bend in a pipe. The following are the objections to this form:—

(*a*) Insufficient depth of water to form a good water-seal.
(*b*) No means of cleansing it if a sediment forms in the bend.
(*c*) No ventilation, see fig. 67A.

Fig. 67 B shows one with a pipe for ventilation of the trap, but this pipe does not allow for cleaning or ventilating the drain beyond, and there is generally a tendency

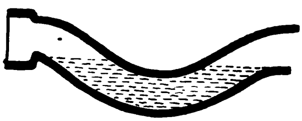


Fig. 67A.—Simple Siphon Trap (Without Ventilation).

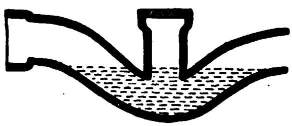


Fig. 67B.—Siphon Trap (With Ventilation).

for the lighter filthy matter to float on the surface and accumulate in this pipe.

A form which is free from these objections is shown in fig. 68. The ventilating pipe may extend above the

surface of the ground; there is another opening with a cap, which may be used to cleap the drain beyond, and the inlet is well above the outlet, which materially assists the flush.

Another good form is *Buchanan's disconnecting and ventilating trap*, see fig. 64.

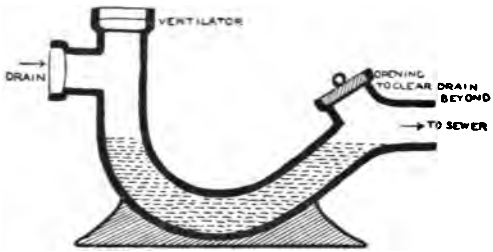


Fig. 68.—Improved Siphon Trap.

A simple siphon trap which may be used for the sink is shown in fig. 69. It is called, from its shape, an "S" trap. It is essential that an opening, fitted with a screw-plug, be arranged at the lowest bend for cleaning it (as shown in the figure.)

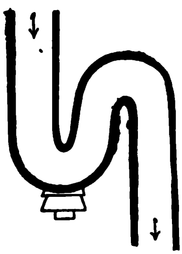


Fig. 69.—"S" Trap for Sink.

Siphonage. There is one danger in connection with the siphon traps; when the trap with the inlet and outlet pipes are running full the pressure of the air on the inlet end, may force the whole of the water out (as in an ordinary siphon). To prevent this *siphonage, or unsealing of the trap by siphon action*, the trap must be arranged so that there is air at the outlet, to counterbalance the pressure at the inlet end. This is best secured by having a pipe which opens to the air at the highest point of the bend. For examples of this see fig. 72. If the whole of the

siphon is inside, the ventilating pipe of the siphon may be carried through the wall. The "Anti-D trap" (fig. 70), so styled by its inventor, Mr. Hillyer, is one which is not subject to siphonage. The outlet is square, and, being larger than the inlet, the whole of the air is not displaced from this end. The bend of the trap is less in diameter than the inlet or the outlet pipes.

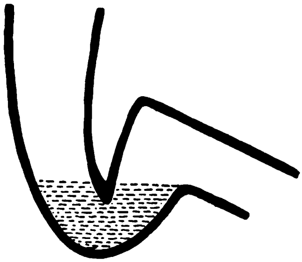


Fig. 70.—Hillyer's Anti-"D" Trap.

Note the arrangements to prevent siphonage in the diagrams of W.C.'s in the preceding figures.

2. **Gully-traps.**

These are useful for washings of the yard, waste water, and rain water, but should *never* be placed inside the house.

The diagram shows a yard gully with a grating above and a moveable pan at the bottom to be lifted out with the

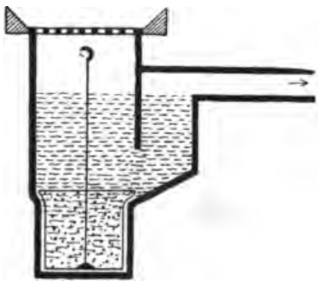


Fig. 71.—Gully Trap with Movable Bucket for Sediment.

rubbish which has fallen into it. The house pipe should not open immediately over the gully, but into an open channel 18 inches from it. (Model bye-laws of L. G. Board.)

Good traps.

1. They should have a water-seal of at least $1\frac{1}{2}$ inches in depth to form a certain barrier to gases.
2. They should have no projections or angles for the deposit of filth.
3. They should be situated so that they can be easily flushed with sufficient force to clear them without causing siphonage.
4. They should be self-cleansing. (Mason's trap, and "D" trap fail here.)
5. They should be ventilated.

Faults in traps.

1. Liability to unsealing through evaporation of the water, if seldom used.
2. Liability to unsealing through siphonage unless guarded against.
3. Pressure of gas may force water out. (Ventilation of drain prevents this.)
4. The water may absorb sewer-gases at one opening until it is saturated and these gases will be given off at the other surface unless frequently used.
5. They always obstruct the flush of water to some extent.
6. Some are filthy and should be discarded altogether if not self cleansing.

The student should make a careful study of the **model arrangement of house-pipes for bath, W.C., and sink,** sketched in fig. 72. Note particularly the following details:—

1. The W.C. cistern is entirely separate from the supply cistern.
2. The soil-pipe is ventilated.
3. The siphon-traps have an air-pipe to prevent siphonage.
4. The waste-pipes from bath and sink over a gully-trap.

PRACTICAL WORK ON CHAPTER VIII.

1. Examine the **different forms of W.C.** which are available, to verify the text-book descriptions.

2. By means of glass tubing, make a **model of a siphon trap.** If water coloured with magenta be poured in, it will be seen that the bend retains water (which acts as a barrier to sewer-gas in a real trap).

3. Make a **simple siphon** by bending a glass tube of about a foot in length, so that one leg is 4 inches and the other 8 inches. When this is

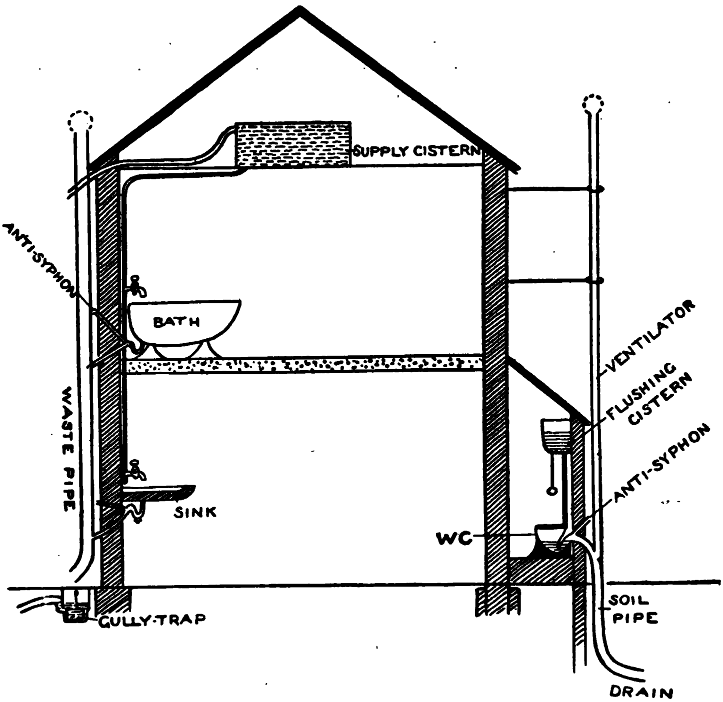


Fig. 72.—House Pipes for Bath, W.C., Sink.

filled with water, and the short end placed in a vessel of this liquid with the longer end hanging over the side, the pressure of the air will force water over the bend and the water will flow until air enters the siphon. This will illustrate siphonage.

CHAPTER IX.

REMOVAL AND TREATMENT OF REFUSE.

Sewage may be defined as water containing certain refuse substances in solution and in suspension. It is composed of:

1. The urine and faeces of human beings and animals.
2. Slop-water, including water used in cooking, washing, cleaning, etc.
3. Rainfall.
4. The waste water of factories.

For a mixed population the daily average of excreta per head may be taken to be 2½ oz. of faeces and 40 ozs. of urine. The manurial value of the urine is about ten times greater than that of the faeces. When diluted with the water from water-closets the addition of these matters to the sewage of a town has very little effect upon the composition or the manurial value of the sewage. According to the first report of the Rivers Pollution Commission the value for agricultural purposes of 12 tons of sewage from towns without water closets is equal to 10 tons of sewage from towns with water closets.

The average compositions are thus compared:—

	Total Solids in Solution.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Total Nitrogen.	Chlorine.	Suspended Matters		
							Mineral.	Organic.	Total.
Midden towns	82·4	4·2	1·9	5·4	6·4	11·5	17·8	21·8	31·9
Water closet towns	72·2	4·7	2·2	6·7	7·7	10·6	24·2	20·5	44·7

The above numbers represent parts per 100,000. As a matter of fact it is quite impossible to prevent access of urine to sewage. This being the case it makes but little difference whether the solid matter is included or not.

Both faeces and urine decompose but slowly if not mixed with water, but when it has been added to them decomposition sets in within 24 hours, resulting in the evolution of foetid organic gases. If these are evolved near the dwelling house they may injuriously affect health. It is important therefore to prevent the mixing of the excreta with water as long as they are retained near the dwelling, and, on the other hand, if they are allowed to mix with water, means must be provided for their immediate and thorough removal.

The treatment of sewage is usually considered under two heads—the conservancy systems and the water carriage systems.

Conservancy Systems.

1. **The Privy or Midden System.** The old-fashioned plan, still often met with in country places, was to dig a hole in the ground at the back of the closet. This received the excreta for an indefinitely long period. If the soil happened to be porous the liquid part quickly percolated downwards and polluted the ground water, while the decomposition and liquefaction of the more solid constituents kept pace with their production, so that such middens never required emptying at all. Where the soil was more impervious the pit gradually filled up and was emptied at long intervals. The more modern midden consists of a comparatively water-tight shallow pit which receives the excreta and into which are thrown the ashes from the house. It should be at least 6 feet away from any dwelling and 50 feet away from any spring, well, or stream. Rain must be excluded by a suitable roof, and proper ventilation must be provided. To enable ashes to be readily mixed with the excreta the seat should be hinged. The capacity should be small so that a removal of the contents is frequently necessary. The floor of the privy must be 6 inches

above the ground outside, and should slope towards the door. It should be made impervious by covering with flags or tiles. Means of access for the scavenger should be available without passing through the dwelling, and, lastly, the midden must not be connected with any drain or sewer. Under these conditions there seems a great deal to be said in favour of the midden system, especially for small houses. Properly managed they should give rise to no pollution of the air, especially if people are instructed to apply the ashes and cinders uniformly over the excreta, thereby ensuring dryness of the contents. The advantages of this method over the water carriage system lie in the fact that there is no possibility of anything getting out of order and that it is independent of all weathers.

The Pail or Tub System. These are really middens on a small scale. The seat of the closet has a tub or pail placed under it for the reception of the excreta. The pail should be made of galvanised iron with a well fitting lid, and must be perfectly water-tight and nearly air-tight. At intervals of not more than a week it is removed and a clean one put in its place. Such is the outline of a system that is undoubtedly superior to the midden system for towns. The details vary in different places. In some—Nottingham for instance—the ashes of the houses—with or without sifting—are added to the excreta by the people using the closets; while in Birmingham and other places a separate tub or galvanised iron bin is provided for the ashes. At Halifax the Goux system is in use. It consists in providing the pails with an absorbent lining of peat, shoddy, tan, or refuse sawdust. On the whole this method has worked well. With frequent and regular removal the pail system works very satisfactorily, and is independent alike of climatic conditions and the ignorance of the lower classes.

Dry Earth System. This is undoubtedly the best of the conservancy systems. Faecal matter, with which dry earth has been mixed, becomes not only inoffensive, but after a short time, unrecognisable as such. This absorbent and deodorising action of earth is dependent upon minute organisms or bacteria which are in the soil. These effect the conversion of nitrogenous matter into ammoniacal

compounds, and these, by processes of oxidation are resolved into nitrites and nitrates. The best soils for this purpose are moderately dry and loose loams, garden soils, dry clay and brick earth. Sand, gravel, and chalk are unsuitable and inefficient. The method of use is to cover each stool at once with one and a half pounds of dry earth. This is found to be sufficient to remove all smell and to form a "compost" which is suitable for potting plants, but is by

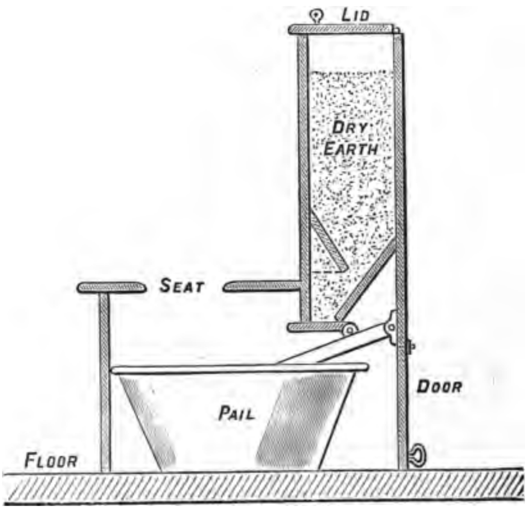


Fig. 73.—AUTOMATIC EARTH CLOSET.

no means a rich or valuable manure. When the pail is full its contents may either be applied at once to the garden or removed to a dry shed where, after frequent turning over and exposure to the air, the earth may be used again as many as eight or ten times. Automatic closets, which apply a measured quantity of dry earth at each use, are obtainable. One is shown in fig. 73. The handle of the closet is connected with a receptacle behind and above the

seat, which delivers the regulated quantity into the pail when it is raised.

The earth closet requires the closest attention and the most constant supervision if it is to be quite free from smell. It should never be placed inside a house. The personal attention which it requires and the difficulty of disposing of the large bulk of residue should prevent this method from ever being adopted in towns. For country houses, farms, asylums, workhouses, etc., where there is usually plenty of space for the storage of the earth, and unlimited labour is available under proper supervision, the earth closet forms almost an ideal method of disposal of excreta.

Disposal of Slop-waters. None of the conservancy systems deal with the liquid refuse. The disposal of this necessitates a system of drainage similar to that which is necessary when water-closets are in use. In small villages and isolated houses the slop-water is often carried by a drain into a hole in the garden where it stagnates and becomes offensive. If run into a pervious cesspool it may pollute neighbouring wells, and if into a stream the result will be practically as bad as if it contained the solid excreta as well. There are several alternative good plans for the disposal of this waste matter.

(*a*) The slop-water may be run into cesspools rendered impervious by cement and well puddled clay. At comparatively short intervals the contents of the cesspool are utilised on the garden ground by means of a pump or hose.

(*b*) Another method is to pass it through a coke or ash filter at a distance from the house.

(*c*) Where the soil is porous the best plan is perhaps by *sub-irrigation*. An ordinary drain conveys the slop-water away from the house and is then connected with a system of porous pipes laid about 5 feet apart at a depth of a few inches below the surface. These pipes are laid with open joints to allow of a free escape of the liquid into the soil. The liquid is purified by the soil and, if necessary, may be collected by a system of under drainage about 3 feet below the surface. As a rule it is found necessary to use an automatic flush tank in connection with this system so as to

send the liquid the whole length of the pipes at each discharge of the tank, otherwise the liquid penetrates only a short distance along the sub-irrigation pipes, which soon become choked with deposit.

The Water Carriage System.

The chief aim of the conservancy systems described above is to utilise as much as possible the manurial value of the excreta, and in villages and country towns this is the proper course, especially as it is of the utmost importance to preserve the purity of the neighbouring rivers and streams. In large towns, however, the case is quite different. Here the waste water can only be got rid of by sewers, and the addition or not of the excreta makes very little alteration in the composition of the sewage. The volume of the sewage, on the other hand, is very greatly increased by the adoption of the water carriage system, in fact an increase of six gallons per head per day must be allowed for this purpose. In many cases such an increase is a matter for very serious consideration, especially with inland towns, where an insufficient fall necessitates the pumping of all the sewage for the purpose of proper treatment by land or otherwise. An absolute necessity for the proper working of water-closets is a **first rate water supply**, and in places where the supply is limited the saving of 6 gallons per head per day is very important. To obviate this difficulty various forms of slop-closets have been devised for utilising the ordinary house waste water to flush the water-closet. These have been described in the previous chapter. Another disadvantage of the universal adoption of water-closets is their liability to be put out of order by frost or by obstruction produced by foreign bodies being thrown into them. It should also be remembered that the lower classes as a whole cannot be depended upon to aid in the removal of the excreta, even to the extent of pulling a chain each time the closet is used. A water-closet stopped up by frost or carelessness is possibly a more active agent in the spread of such diseases as typhoid fever than a pail-closet or even a modern midden,

because in the former case the receptacle is immediately filled to overflowing with excreta and water, and these soon get scattered over the floor of the closet and often about the yard outside. This matter eventually dries and is scattered through the air in the form of dust, and may be an important factor in the spread of disease. Pails should still be provided by the authorities for the use of the very poor, ignorant, and reckless classes who cannot be trusted to keep water-closets in a proper condition. The liability of water-closets to all kinds of malicious injury is another argument against their adoption for these classes. Moreover, it cannot be denied that the connection of the closets with the sewers has, in many places, especially in London, appeared to lead to an increased prevalence of typhoid fever, diphtheria, and similar diseases. This might possibly have been prevented by greater care in the construction of the sewers, and more thorough methods of disconnection by proper traps, but at the same time it shows that the system of water-closets has several very important disadvantages. However, when carried out under proper conditions and favourable circumstances there is no question that the water carriage system is the cleanest, most convenient, and cheapest method of sewage removal.

Sewers. Before the introduction of water-closets many towns had old fashioned pervious sewers which served to take away the waste and surface water, and at the same time acted as land drains because they readily admitted the subsoil water. In some towns these sewers are still used for the removal of the sewage under the new conditions, and generally with very unsatisfactory results. The best plan is to leave the old sewers to deal with the storm water and to construct new impermeable sewers for the removal of waste water and sewage from the dwellings and water-closets. Such a method is called the *separate system*, as distinguished from the *combined system*, where one set of sewers serves for the double purpose.

The advantages of the separate system are obvious. The ordinary sewage of a town is a known and fairly

constant quantity, being practically the same as the water supply. It is therefore an easy matter to construct sewers of the proper size to deal with the sewage. Under these circumstances the sewers need only be of a comparatively small size. All rain water from roofs, yards, etc., must be conveyed by separate pipes either into a distinct set of underground pipes or, when the gradients are sufficient, into channels at the sides of the streets. These, at convenient points, discharge into the stream which forms the natural drainage bed of the district. The sewers proper convey the sewage to the sewage farm, where it is dealt with before being discharged into the river. Under these conditions, the sewage is not only fairly constant in volume but is also uniform in composition when thus protected from dilution with storm waters, and its purification is therefore a much easier matter than when it is very concentrated one day and very dilute the next. Other advantages of the separate system are that the sewers, being smaller and with smooth walls, are more uniformly filled and more frequently flushed than the large brick sewers of the combined system; and lastly the cost of the separate system is very much less. Of course the system has some disadvantages: for instance, the fact that each house necessarily has two sets of drains obviously gives opportunity to careless builders to connect pipes with the wrong system. The flushing effect of the storm waters on the sewers is lost, and, in addition, the water that runs directly into the river is occasionally, especially after a period of drought, nearly as foul as ordinary sewage.

In the combined system it is necessary to construct sewers of a sufficient size to take a large part of the rain falling during heavy storms. Storm overflows are generally provided, consisting of channels communicating with the main sewers at a higher level than that of the ordinary sewage. Unless this precaution is adopted a sudden storm will deluge the sewage farm with a vast quantity of very dilute sewage, which it is out of the question to attempt to treat in the ordinary way. In these cases it is usual to provide large coarse filter beds of coke, breeze, or such cheap material as may be available, into which the water

may pass. From these the effluent is passed directly into the river.

In the construction of sewers the following are the chief conditions to be fulfilled :—

1. The flow of sewage should have as uniform and constant a velocity as possible. To achieve this sewers up to

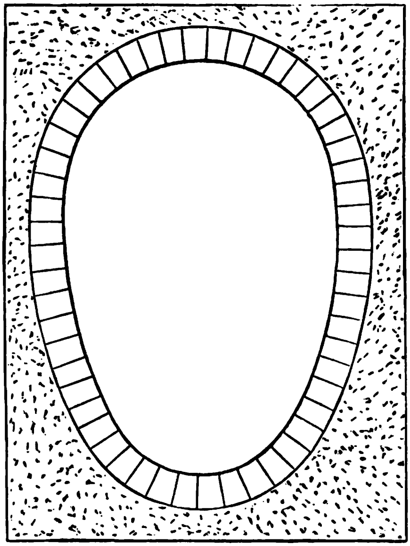


Fig. 74.—Egg-Shaped Sewer.

18 inches in diameter are generally made of well-glazed earthenware socket pipes. Other materials include cement, concrete, and iron. Iron pipes have the advantage of being made in 9 or 12 feet lengths, and therefore fewer joints are necessary. For larger sewers the egg shape with the small end downwards is now universally adopted, and they should be made of well-burnt, tough, impervious bricks set in Portland cement and laid on

concrete. The advantage of this shape is that when the depth of the stream is diminished the friction is also relatively reduced, instead of being as in every other form of sewer relatively increased.

2. The velocity of the flow should be sufficiently great to keep in motion any solid particles, but not more than this, as the greater the velocity is the greater the wear and tear of the masonry. The regulation of the velocity is attained by adapting the fall or gradient to the size of the sewer. Sewers of 1 to 2 feet in diameter should have a gradient sufficient to produce a velocity of not less than 2½ feet per second, and the velocity in larger sewers should never be less than 2 feet per second. If the velocity exceeds 4 feet per second it is found to wear away the brickwork very quickly, especially if the sewage contains much sand or grit. The larger the sewer the less is the gradient required to produce the same velocity, provided that the volume of sewage in each is proportional to the square of the diameter. Thus

(1)	A fall of	20	feet per mile,	with a	sewer	1	foot in	diameter,
(2)	,,	10	,,	,,	,,	2	,,	,,
(3)	,,	4	,,	,,	,,	5	,,	,,
(4)	,,	2	,,	,,	,,	10	,,	,,

will all produce the same velocity of flow if the volume of the sewage in (2), (3), and (4), is respectively 4 times, 25 times, and 100 times greater than in the first case (Parkes).

3. The junctions and bends must be made in such a manner as to prevent the deposition of sediment. For this reason all junctions must be made as obliquely as possible, and so arranged that the flow in the tributary sewer is in the same direction as in the main. If the sewer curves, the radius of the curve should not be less than ten times the diameter of the sewer. Properly constructed and regularly flushed sewers should never require the removal of deposits, and the fact that the sewers of all our large towns require the constant services of labourers forms a serious indictment against their method

of construction. To enable a sewer to be properly inspected *manholes* should be provided at intervals of not less than 100 yards, and are particularly advisable at all junctions and bends. Manholes are shafts sunk from the surface of the road to the sewer, and end in a chamber built of brickwork set in cement. The sewer and its tributary meet in this chamber, being continued along the floor in the form of half pipes set in concrete. A man entering the inspection chamber will therefore be able to tell at a glance whether there is any deposit at the junction. These manholes may also be utilised for flushing the sewers. In

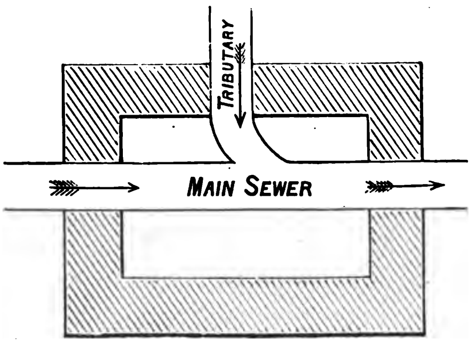


Fig. 75.—PLAN OF FLOOR OF INSPECTION CHAMBER.

some towns it is very difficult to allow a sufficient gradient to the sewer, and consequently deposits are bound to occur unless arrangements are made for periodical flushing. The best method of preventing the formation of deposits is to place automatically discharging siphon flush tanks at various points. These must be supplied with water by a tap connected with the town supply at such a rate as to cause the sudden discharge of the contents at regular intervals of about 12 hours or less.

Ventilation of sewers. Before discussing the ventilation of sewers it is important to clearly define the distinction between *sewer air* and *sewer gas*. By sewer air is meant

the air that is present in the sewer under ordinary conditions. Recent investigations have shown that sewer air rarely contains bacteria from the sewage with which it is in contact. In fact the results of some of these experiments show that although sewer air contains more CO_2 and organic matter than ordinary air, the number of bacteria may be less than in ordinary air. Sewer gas on the other hand is the gas that is given off in large quantities by stagnant sewage or putrefying deposits. This probably contains various micro-organisms which are most likely the cause of the many morbid conditions that are induced by exposure to sewer gas. The most generally recognised effects are vomiting, diarrhoea, headache, chronic blood-poisoning, and diphtheritic sore throats.

The possibility of the sewer air being contaminated by sewer gas should cause every one to realise the importance of thoroughly ventilating sewers; and at the same time to avoid every chance of it entering houses in a comparatively undiluted condition. Not only is it of the utmost importance to have numerous openings in sewers for ventilation, but also to provide a free escape for sewer air in case of a sudden increase in its pressure, such as may be produced by the rapid increase in the volume of sewage which takes place during the early part of the day and during a heavy rainfall, or by the blowing off of steam from boilers into the sewers. Variations in the temperature of the outside air also cause movements of the sewer air, and a fall in the barometric pressure causes the gases dissolved in the sewage to be given off.

The simplest and most efficient plan of ventilating sewers is to provide openings from the surface of the road into the sewer at intervals of not more than 100 yards apart. These should be placed as nearly as possible in the centre of the road, and answer their purpose best when they form part of a manhole and inspection chamber. The opening must be covered with an iron grid, and a tray placed beneath in such a way as to catch the mud and stones that may fall through, and at the same time allow of free passage of air around it. This dirt-box should be capable of removal from the road. Street gullies should always

be trapped in order to prevent the solid débris entering the sewer, and to avoid any escape of sewer air close to the foot paths and houses.

Disposal of Sewage.

The question of sewage disposal has necessarily to be divided into at least two classes—(1) the best method to be adopted for country houses and small villages, and (2) the different ways of sewage treatment and disposal by towns.

Cesspits or Cesspools. If a country house or small isolated village has water-closets the entire sewage, including slops, should either be conveyed to a distant meadow and disposed of by irrigation or sub-irrigation, or run into a cesspit. If a cesspit is used it should be at least 50 feet away from any house, and at least 100 feet away from any well, spring, or stream. It must be surrounded with well puddled clay from 6 to 9 inches thick, and lined with good brickwork set in cement in order to prevent any leakage and consequent fouling of the ground-water. The best plan is to construct it with a shallow chamber which receives the sewage, and a deeper chamber, separated from the first by a vertical grating, which receives the more fluid constituents. An arched roof must be provided, and proper ventilation must not be omitted. In fact, three openings are necessary, one for the purpose of gaining access in order to cleanse the cesspool, the second for a ventilating pipe, and the third for fixing a pump. This arrangement closely resembles the treatment of town sewage in septic tanks. When the house pipes and drains are all completely disconnected by means of traps this method is found to work extremely well, The liquid from the deep chamber is distributed at intervals over gardens or fields by means of a pump and hose. The shallow chamber requires very little attention. At very long intervals it may require to be dug out.

Discharge of Sewage into the Sea. For towns near the sea this affords the readiest means of getting rid of sewage.

If adopted it must, however, be subject to certain conditions. These are :—

(1) The sewage must be carried well out to sea beyond low water mark, so that the outlet will always be well under water. A place should be selected, if possible, where there is a fairly constant current seawards. If this condition is not fulfilled the sewage will be conveyed up and down the shore or to and from the coast by the tides, and the result will be the black slimy deposit on the sands which is so often seen near seaside towns.

(2) The end of the sewer should be provided with a tide-flap capable of opening outwards only, in order to prevent the rising tide entering the sewer and forcing back the sewage and sewer air. In any case, however, there will result a stagnation and accumulation of the sewage in the sewers during high tide, necessitating the provision of tank sewers for the storage of sewage that flows down during this interval.

(3) The prevailing winds should also be studied to prevent the possibility of floating faecal matters being blown back on to the beach. Most seaside towns would probably greatly improve their sewage disposal by introducing some modification of the septic tank method of treatment which would result in the solution or digestion of most of the albuminous matters.

Discharge of Sewage into Rivers. For inland towns it is obvious that the water of the sewage must ultimately find its way to the neighbouring rivers and steams. By the Rivers Pollution Acts of 1876 and 1890 it is made illegal to pollute any stream or river by allowing crude sewage to flow into it. Some process of purification must therefore be adopted in order to produce from the sewage a liquid that may be discharged into a river without any fear of its subsequent putrefaction. Before describing the different methods in detail it is important to clearly understand what has to be done to the sewage, and what changes must be brought about in its chemical composition before it can be discharged into a river. It must be remembered that sewage contains two kinds of impurities which have to be treated—(*a*) the suspended impurities and

(*b*) the dissolved. By paying attention only to the removal of the suspended impurities by various precipitation processes it is possible to produce a perfectly clear, inodorous, and tasteless liquid, which, nevertheless, contains a large amount of organic matter in solution. If this is discharged into a river it subsequently undergoes decomposition and putrefaction resulting in the production of foul gases and the deposit of black foetid mud in the bed of the river.

This organic matter in solution has always been the chief difficulty in the problem of sewage disposal. It is absolutely essential that it should be converted into inorganic substances before being discharged into a river. Until lately this conversion of organic into inorganic substances has always been accomplished by land treatment, but more recently the septic tank method and the treatment by bacterial filters have been introduced in order to bring about the necessary change much more quickly and simply. The surface soil, to the depth of 3 or 4 feet swarms with bacteria whose functions are to convert the nitrogenous organic matter into compounds of ammonia, and to further oxidise these into nitrites and nitrates. This process, known as "nitrification," is continually going on in the soil whether sewage is introduced or not, but by the careful addition of sewage this property of the soil may be very greatly developed.

Purification of Sewage.

Many of the processes that have been employed until recently, and which are still used in some places, will in all probability soon have merely an historical interest. They will therefore receive only very brief attention, and are summarised under the heading chemical treatment.

Chemical Treatment. This includes the following methods:—

(*a*) *Precipitation processes.* The sewage is run into tanks and the subsidence of the suspended particles is assisted

by the addition of some precipitant, *e.g.* lime, alum, or some salt of iron. The precipitates formed by the alum or iron help to carry down the finer suspended particles in the sewage and thereby hasten the separation of it into a sediment or sludge and a clear liquid.

(*b*) *The A.B.C. process* consists in the addition of alum, blood, clay, and charcoal to the sewage. This produces a clarified sewage which is inodorous but not in any way fit to be discharged into a river.

(*c*) *Electrical processes.* The electrolysis of sewage results in the formation of oxidising substances called hypochlorites. These oxidise the sewage and partly sterilise it, but the liquid requires additional treatment. In the *Hermite system* the sewage is treated with partially electrolysed sea water.

(*d*) *The amines process* is to treat the sewage with milk of lime and a small quantity of herring brine. This is said to produce an inodorous sludge and effluent.

All the above processes result in the division of the sewage into two parts, (*a*) the sludge, and (*b*) the clarified effluent. The disposal of both these presents considerable difficulties. (*a*) The *sludge* of small towns in agricultural districts can generally be disposed of to local farmers. This method, however, rarely guarantees its regular and systematic removal, so that it is liable to accumulate and undergo putrefication, thereby causing a nuisance. At the same time it must be remembered that it forms a very poor manure. In other cases, as in Birmingham, it is forced up in a semi-fluid condition, and run along carriers on to the land, and when it has become comparatively solid, through evaporation and percolation into the earth, it is dug into the soil. Another method is to press part of the moisture out of the sludge by hydraulic filter presses, by which a solid cake, containing about 50 per cent. of moisture is produced. This may be stored up without causing much nuisance and can be disposed of as manure, or it may be burned and manufactured into cement. In London the sludge is pumped into steamships and discharged into the sea at some distance from land.

(*b*) The clarified *effluent* must be dealt with in one of three ways:—

(1) By intermittent downward filtration.
(2) By broad irrigation.
(3) By some form of bacterial filter.

The first two methods include what is generally called "sewage farming," though strictly speaking this term should be applied only to broad irrigation. Whatever method is adopted it must be clearly understood that no system of disposing of or treating sewage at a profit has yet been devised, and probably never will be. The only question to consider is which of the various methods is likely to give the best results and the least expense.

(1) *Intermittent downward filtration* may be defined as "the concentration of sewage at short intervals on an area of specially chosen porous ground, as small as will absorb and cleanse it, not excluding vegetation, but making the product of secondary importance." The quantity of land required is about one acre for each 1000 of population. The land is laid out in successive terraces, along the upper side of which is a channel or carrier made in concrete. At right angles to this channel small feeders are made in the soil by means of a plough, so that the clarified sewage can be distributed over the land, and by means of sluices it can be directed on to any part of the area. The surface of the land must be levelled and under-drained by porous tile drains, laid at a depth of 5 or 6 feet. From these the effluent should, if possible, be allowed to run over a meadow before entering the river. It is important to divide the filtering area into four equal parts so that each part may receive sewage for 6 hours, and have an interval of 18 hours for rest and aeration. By an arrangement of ridges and furrows it is possible to raise certain root crops such as beet, mangold wurzel, or swede. The sewage flows down the furrows, while the vegetables are grown on the ridges. The roots of the vegetables assimilate the organic part of the sewage and thus aid its

purification, while the stalks and leaves, being high above the sewage, are not contaminated.

(2) *Broad irrigation* differs from intermittent downward filtration by securing the maximum growth of vegetation for the amount of sewage supplied. A much greater area of land is required, generally at the rate of one acre for every 100 of population. Land should always be chosen so situated that the sewage will flow to it by gravitation. Under-drainage is desirable at a depth of 3 or 4 feet below the surface. The carriers are arranged about 30 feet apart, along ridges, with furrows running at right angles to it to insure uniform distribution of the sewage. Care should be taken that the sewage passes through the soil, and not merely over it and into the river; surface flow alone rarely gives satisfactory results, although in some districts it seems inevitable owing to the stiff clayey nature of the soil. Rest is just as important for the land in irrigation as in downward filtration, in order to secure proper aeration, and to prevent the soil becoming clogged with the sewage, which must reach the ground in as fresh a state as possible.

The most suitable crops for a sewage farm are Italian rye-grass, roots such as mangold wurzel, and cabbages, With regard to Italian rye-grass a report to the Local Government Board states that it "is probably in all respects the most advantageous crop to be grown under sewage, as it absorbs the largest volume of sewage; occupies the soil so as to choke down weeds; comes early into the market in spring; continues through the summer and autumn, bearing from five to as many as seven cuttings in the year, and producing from thirty to fifty tons of wholesome grass upon each acre." The drawback to it is that it does not keep well, so that if it not disposed of very quickly it is wasted. For this and similar reasons it has been found that, to reap the greatest possible profits from a sewage farm, a dairy farm should be established, so that the produce may be converted directly into meat and milk. These products of a sewage dairy farm differ in no way whatever from meat and milk produced on ordinary farms.

BIOLOGICAL METHODS OF PURIFYING SEWAGE.

Strictly speaking, the treatment of clarified sewage by intermittent downward filtration and by broad irrigation are truly biological methods since the purification is effected by micro-organisms in the soil, but it is preferable to reserve this term for those methods recently introduced, and which really consist of the adoption of Nature's own methods of purifying organic matters. Reference has already been made early in this chapter to the fact that a cesspool which receives all the sewage from a house only requires emptying at extraordinarily long periods if it is merely a hole dug in porous soil, while if made impervious it is found to contain practically no solid matter when it is emptied. This proves conclusively that Nature must be able to dispose of the solid constituents of the sewage and cause them to dissolve in the surrounding liquid. As a matter of fact, this is accomplished by micro-organisms which may be conveniently divided into three classes:—

(1) Those which can only work in the absence of oxygen (called anaerobes).
(2) Those which can only work when oxygen is present (called aerobes).
(3) Those which can work either in the presence or absence of oxygen (called facultative aerobes).

It seems extremely probable that the first class, the anaerobes, are most efficacious in causing the liquefaction of the solid organic matter. This is accomplished in a manner closely analogous to the process of gastric digestion, the nitrogenous material being converted into soluble substances resembling peptones. The aerobic organisms are able to convert these substances into salts of ammonium, and eventually into nitrites and nitrates. The advantages of any process that deals with the whole of the sewage in this way are obvious. The cost of useless chemicals and the expense of applying them is saved, and there is no sludge to deal with. There is, moreover, not the slightest doubt that the chemical treatment of sewage hinders the purification of the clarified effluent by the soil,

while the biological process produces an effluent which is more readily susceptible to the agencies which effect its ultimate purification.

To treat sewage by biological processes the following steps are essential:—

1. The sewage is first run into a detritus tank, where the heavy inorganic particles, such as the coarse grit from the surface of roads, subside.

2. The sewage has next to be liquefied by some digestive action such as is carried on in

(*a*) The "Septic" tank system, or
(*b*) A coarse grain bacterial filter.

3. The nitrification of the liquefied sewage must now be accomplished by

(*a*) Finer filters, or
(*b*) Some form of land treatment,

or by combinations of these methods.

The Septic Tank System (Cameron). The sewage is led into a large covered tank of a capacity equal to at least 24 hours flow of sewage. Light and air are excluded as far as possible. The rate of flow is arranged so that each part of the sewage remains in the tank for 24 hours. The liquefaction of the solid organic particles takes place with astonishing rapidity owing to the action of the anaerobes. The liquid is then aerated by being run over a weir and cascade arrangement and is now either available for land treatment or it may be passed through a fine grain filter bed. These aerating filter beds are made of particles varying from ¼ to 1 inch in diameter, and may be constructed of any hard and durable material, *e.g.* coal, coke, ballast, or gravel. Here the albuminoid material is oxidised by the aerobes into nitrites and nitrates, the result being a remarkably clear, odourless, and inoffensive liquid, which may be passed into a good sized river, although it is always advisable to pass it first either through land or over water meadows.

The drawback to the septic or bacterial tank system is the excessive cost of constructing large covered tanks of

sufficient capacity to hold such an immense quantity of sewage as will be received from any town during 24 hours. Recent experiments seem to prove, however, that the covering is unnecessary, a fact which of course considerably reduces the cost. In Birmingham, large open air tanks are used through which the sewage flows in a very slow stream. After a short time the surface of the sewage becomes covered with a peculiar scum or covering which is believed to play an important part in the liquefying action that is going on. They give off no unpleasant smell although a large quantity of gas is evolved.

The Large-grain Bacterial Filter. In this system the sewage is passed through a detritus tank in which it deposits any particles of grit, and then through a filter of large particles varying from 1 to 2½ inches in diameter. In some places the sewage is retained in the filter bed for 8 to 12 hours and then released, whereas in others the process is one of slow continuous flow. The filter must be worked intermittently in order to allow of aeration and enable the liquefaction of the organic solids which have been arrested by the filter to be completed. The liquid from these beds may now be disposed of on land or passed on to the small-grain filters for nitrification to be completed.

The Kitchen Refuse.

All animal and vegetable refuse from the kitchen must be burned, and should never on any account be thrown into the dustbin or ashpit. Refuse, such as cabbage leaves, potato peelings, bones, and waste food are very liable to become objectionable if thrown into the dustbin instead of being burned. Only a strict adherence to this rule will prevent a dustbin from becoming a serious nuisance.

A convenient receptacle for ashes, soot, and inorganic refuse is a dustbin consisting of a wooden tub or galvanised iron box. If an ashpit is built, it should conform with certain regulations. The best possible conditions for an

ashpit or dustbin are attained when the following rules are adhered to :—

(1) It must be at least six feet from the wall of the house.

(2) Means of emptying it should be provided without carrying the contents through the house.

(3) It should be small—not above 6 cubic feet in capacity—to ensure frequent emptying.

(4) Only indestructible matter must be put into it.

(5) A good lid or water-tight roof must cover it to protect the contents from rain, as moisture favours decomposition.

If an ashpit is built, it should fulfil the following conditions in addition to rules (1), (2), and (4) above.

1. It must be made of impervious material, such as brickwork set in cement.

2. It should be roofed over and properly ventilated.

3. The floor should be three inches above the level of the ground outside.

4. There must be a door of convenient size for removing the contents.

5. There must be no connection whatever with any drain.

The best method of disposal of the dustbin refuse is to burn it in some form of destructor furnace. The proportion of cinders in the refuse is usually sufficient to ensure the complete combustion of all the ingredients. Many destructors have been introduced but a description of any them is beyond the scope of this book. The residue consists of ash and clinkers, and may be used for road mending, or it may be ground up and mixed with lime in order to make an excellent cement.

CHAPTER X.

WATER.

Water. Water is absolutely essential for health.

A. *In the body* it keeps the blood fluid and thus helps (1) to carry food material to all parts; (2) to carry away the waste material of the tissues; (3) to regulate and keep uniform the temperature.

B. *In the house* it is used to remove and carry away waste material and dirt. (1) To cleanse the skin; (2) to wash clothes; (3) to cleanse the house and household utensils; (4) to cleanse house-pipes and drains, and to carry away waste and excrementitious matter to the sewers.

The various sources of water supply are clearly treated in the *First Stage Hygiene* in this series. The usual sources of water supply include: (1) rain water, (2) upland surface water, (3) springs, (4) wells, (5) rivers, (6) lakes.

(1) *Rain water.*

- (*a*) Purest natural water.
- (*b*) Contains no mineral matter, but has dissolved gases from the air.
- (*c*) May contain soot from air, and washings from roofs.

(2) *Upland surface water* is collected from moors and hills. It is soft and has great solvent action on lead. To prevent this action, it is sometimes filtered through limestone to make it harder.

(3) *Springs.*

- (*a*) Pure water is obtained from springs which issue from beds of sand and gravel.
- (*b*) Hard, but well-aerated and palatable water issues from springs in chalk or limestone.

(4) *Wells* are artificial springs.

(*a*) *Surface* or *Shallow Wells*—no matter what the depth—are those in which water is obtained from the surface layer. See fig. 35.

(*b*) *Deep Wells* are those in which the well passes through an impervious layer to water underneath.

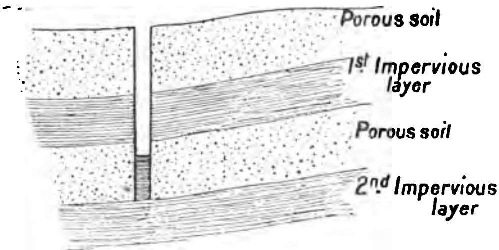


Fig. 76.—Deep Well.

esian Well is a deep well, tapping water een two impervious layers, in which the r level is at least as high as the level of ground where it is sunk, so that the water ses in the well to the ground level, or above it.

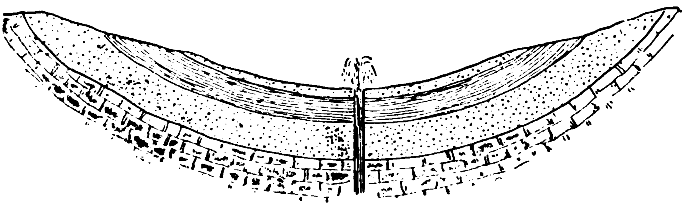


Fig. 77.—Artesian Well.

Water from surface wells is liable to pollution, from sewage or other impure matter soaking in.

Deep well water is free from organic impurities, but is

harder, owing to the dissolved matter it has accumulated during its passage through the rocks.

(5) *River water* usually contains suspended matter and needs filtration. It is well aerated and not so hard as spring or well water. There is, however, a danger from drainage which may enter the river in its course. Owing to the water of streams being well oxygenated there is a tendency to self-purification which lessens the impurities present.

(6) *Lake water* is generally very pure and soft with scarcely any organic impurities.

(7) *Distilled water* is pure, but tasteless and insipid, through lack of aeration. On board ship it is aerated, by being allowed to drip from casks placed on a shelf.

Modes of supply. In villages and rural districts the expense of a common water supply and distribution is too great, so the inhabitants depend on small surface wells, and springs. For towns, however, this is impossible. The chief sources utilised for towns are: (1) rainfall on upland surfaces, (2) rivers, (3) deep wells, (4) lakes.

(1) *Upland surface water.* Storage reservoirs are formed to equalise the supply and demand. They are generally made by impounding the water from the gathering grounds in such a position that the town or community may be supplied by gravitation. The capacity of the storage required is given by Hawksley's formula, $D = \frac{1000}{\sqrt{F}}$, when D is the number of day's supply which should be stored, and $F =$ mean annual rainfall in inches of three consecutive dry years.

Thus if $F = 25$ inches, we have $D = \frac{1000}{\sqrt{25}} = \frac{1000}{5}$

$= 200$ days supply should be stored.

Having found D, if the daily amount required is known, the capacity of the reservoir is then found.

Capacity $=$ daily amount $\times$ no. of days supply req$^{d.}$ (D).
If there is a population of 30,000 requiring 30 gallons each daily,
Capacity $= (30{,}000 \times 30) \times 200 = 180{,}000{,}000$ gallons.

From the impounding reservoir the water is conducted along aqueducts to smaller reservoirs called service reservoirs, which are usually covered and made to hold one or two days supply.

(2) *Rivers.* The water is taken from moving water and not from a stagnant part. It is led into subsiding reservoirs, which contain 2 or 3 days supply, and from these it is conducted to filter beds, and afterwards pumped up to service reservoirs.

(3) *Deep Wells.* The water (except in the case of Artesian wells) is pumped up into reservoirs for distribution. This is not a source which can be drawn on indefinitely as each well drains a considerable area, and doubling the number of wells will not double the supply.

(4) *Lakes.* Some large towns obtain their water supply from lakes. *E.g.* Glasgow from Loch Katrine, Manchester from Thirlmere in Cumberland, and Liverpool from Lake Vyrnwy, an artificial lake in Wales, made by impounding the water of the River Vyrnwy.

Filters. The purification of water on a large scale is usually effected by sand filter beds. The water is first passed into settling reservoirs, where sedimentation takes place for 24 hours. It is then allowed to flow on to the filter bed which consists of layers of sand and gravel. The new works at Hamburg have 40 inches of sand and 24 inches of gravel in different sizes, arranged so that the upper finer material cannot pass into the lower coarser material, nor can the lower material be carried away by the descending water.

The new waterworks at Berlin have (*a*) fine sand 24 inches, (*b*) gravel 12 inches, (*c*) larger stones 12 inches.

The water is collected by pipes or channels which convey it to reservoirs.

Action of the Filter. The action is partly mechanical, for the suspended matters are removed, but, as Piefke first showed, sand alone will not remove micro-organisms from water. When a filter has been in use for a few days, a peculiar slimy gelatinous layer is formed in the surface, consisting of colonies of bacteria combined with suspended matter, and it is the vital action of the bacteria in this

layer which is of the greatest importance. Their action is to oxidise organic impurities and to destroy injurious micro-organisms. Hence this layer should not be broken unless it becomes too dirty, through suspended materials, when it requires removing. In addition to this the oxygen

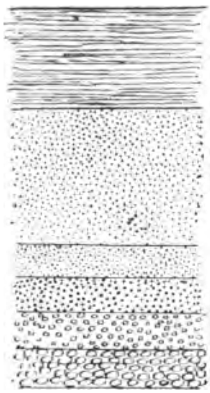


Fig. 77A.—SECTION OF A FILTER BED.

in the spaces in the lower layers helps in oxidation of organic matters.

For success in filtration:—

1. The filter-beds should be used intermittently and should be exposed to the air when not in use.
2. When the upper layers become blocked up with impurities they should be removed and replaced with fresh sand, but care should be taken as to the disposal of the water which passes through the first day after removal. It should be pumped up to be filtered again.
3. Filtration should be slow, only 3 or 4 inches per hour.
4. The filter beds should be completely renewed every 2 years.

Domestic Filters. Greater popular delusion exists on the subject of filtration than on any other connected with health, for there are many different kinds of filters in use *which afford no protection whatever*, and in some cases are positively dangerous.

Animal Charcoal was formerly considered one of the best filtering materials; later experiments, however, have shown that, although the oxygen in the air of the pores oxidised to some extent organic impurities, yet it did not get rid of the bacteria, for some of these find their way through the charcoal and pass on with the filtered water. At the same time phosphates and nitrates are added to the water from the charcoal, and these form a nutritive medium for these organisms so that they multiply very fast thus making the water worse after filtration than before.

Other *substances used for filtering* are spongy iron, polarite, manganous carbon, carbolite, and silicated carbon. There are many varieties of filters but few are *germ-proof.* The report of Dr. Sims Woodhead and Dr. Wood, after an examination of over twenty varieties states in conclusion:—

"Before concluding, we may be permitted to make a few observations regarding the testimonials and statements published by the makers of the filters, imperfect from the bacteriological point of view, which we have reported on. These filters may, as we have already said, materially increase the risk of acquiring infective disease, but in addition to this they are to be looked on as an unmitigated evil, in so far as they give rise to a false sense of security, which prevents the precaution of boiling the water being taken, where necessary. We should recommend accordingly, that the vendors should either withdraw these statements, or at the very least, satisfy themselves, by taking independent expert evidence, that they are justified in making these claims in regard to the prevention of disease by the use of their filters."

The two most satisfactory filters are the Pasteur-Chamberland filter and the Berkefeld filter, both of which may be relied upon.

The **Pasteur-Chamberland** filter consists of a cylinder of unglazed porcelain, closed above, and terminating below in an open nozzle. This is enclosed in another vessel, having a space between the two both above and at the sides, into which the water passes. During filtration it has to pass

through the porcelain; it subsequently flows out of the nozzle at the rate of 2 or 3 quarts per hour, when under a pressure of $1\frac{1}{2}$ to $2\frac{1}{2}$ atmospheres, such as is frequently present in the pipes of a water service,—while without pressure it drips slowly. The filter is easily cleaned, as the porcelain cylinder can be taken out, and the matter on the outside scrubbed off, the cylinder being afterwards sterilised by boiling. This kind of filter was used by M. Pasteur for sterilising fluids in the laboratory, and his assistant M. Chamberland made use of the idea to make larger filters for water.

Fig. 78.—Filtering Material of Berkefeld Filter magnified 600 times.
(By permission of Berkefeld Filter Co.)

The **Berkefeld** filter is similar in principle to the Pasteur-Chamberland but is made of diatomaceous earth (see fig. 78). The pores of this are larger than in the porcelain, and the action is more rapid.

Under a pressure of 35 to 40 lbs. per square inch, a cylinder will yield 20 gallons per hour.

Fig. 79 shows a single cylinder with fittings, which will illustrate the method of fixing either a Berkefeld or a Pasteur-Chamberland Filter.

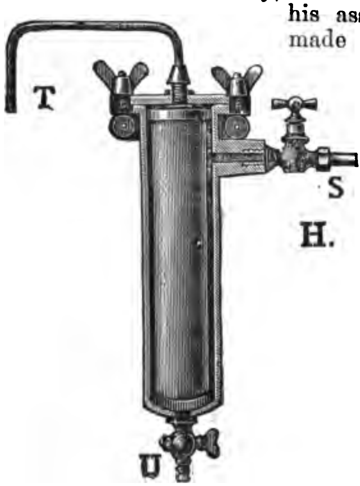


Fig. 79.—Berkefeld Service Pressure Filter.
S, Water Supply. T, Filtered Water Out-let. U, Flushing Tap.
(By permission of Berkefeld Filter Co.)

The cylinder of the

Berkefeld filter is made thicker so that the internal cavity is less than in the Pasteur-Chamberland filter.

Fig. 80 shows two forms of the Berkefeld filter which are suitable for use where no pressure is available, but of course the rate of flow is small—about 1 pint per hour for each filtering cylinder. Filters may be increased in size by increasing the number of cylinders. The Berkefeld

Fig. 79A.—House Filter fitted to Service Pipe over Sink.
(By permission of Berkefeld Fil'er Co.)

filter is cleaned and sterilised in the same way as the Pasteur-Chamberland. The action of each of these filters is mechanical, and not vital or chemical. The pores are very small, and exclude suspended matter, which forms a slimy coating on the outside, but they are not smaller than the diameter of bacilli. These are supposed to be retained in the pores by a kind of molecular attraction, and the

conditions there are unfavourable to growth. The slimy layer which forms on the surface, and the bacilli in the pores render the regular cleaning and sterilising of the cylinders a necessity, even in the case of the best filters, and if this is done, there is no danger whatever of the spread of water-borne diseases.

The Berkefeld filter is obtainable in England; while other germ-proof filters (Pasteur-Chamberland) can be

Fig. 80A.—Glass Table Filter.
(By permission of Berkefeld Filter Co.)

Fig. 80B.—Stoneware Filter containing or Cylinder.
(By permission of Berkefeld Filter Co.)

purchased on the continent. On account of the rapidity of its action compared with these latter, it is the most suitable for ordinary use where pressure is available.

The **Traveller's Pump Filter** is a compact, convenient, and most efficient combination of filter and pump, enabling travellers in any country to obtain a rapid supply of wholesome water from any source. These have been used with great success in many military expeditions, and larger

sized "Pump Filters" have been employed in the recent South African War.

In fig. 81 *G* is the piston which is raised to allow the pressure of the air to force water through the lowest opening into the barrel of the pump. When the piston is made to descend the water is then forced into the left-hand part, *through* the filtering cylinder *A*, and out of the upper nozzle.

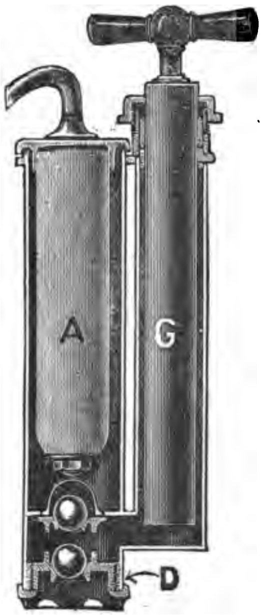


Fig. 81.—Traveller's Pump Filter.

(By permission of Berkefeld Filter Co.)

The characteristics of *a good filter* are:—

1. It should prevent the passage through it of suspended matter, and all micro-organisms;
2. It should add nothing to the water;
3. It should be easily cleaned;
4. It should not be so costly as to be prohibitive;
5. It should oxidise and render harmless any dissolved organic impurity.

Other methods of purification:—

1. *Boiling* to kill micro-organisms, and to soften it.
2. *Adding lime* to soften it. CO_2 is present, which enables the water to hold carbonate of lime in solution. The lime added joins with this CO_2, and all the carbonate of lime is precipitated.
3. *Adding alum* or other chemicals.
4. Distillation.

Distribution of Water.

Water is conducted along pipes from the service reservoirs. The mains are the largest pipes; they pass under the street, and from them *service pipes* branch to the houses.

Water may be supplied to the houses either on (*a*) the constant system, or (*b*) the intermittent system.

(*a*) **Constant System.** The pipes are constantly filled with water from the reservoirs, so that there is no necessity for cisterns, except for water-closets and the kitchen boiler.

Advantages.

1. The water is always available for use. (Specially valuable in the early stages of a fire.)
2. The pressure of the water in the pipes is always greater than that of the air, so there is no danger of sewer gas or ground air entering the pipes.
3. There is no risk of contamination through storage in cisterns.

Disadvantages.

1. There is a danger of waste or misuse of water in some parts in times of heat, drought, or frost, which may cause a scarcity in other districts.
2. Stronger and more perfect fittings are required than in the other system.
3. More water is used. (With careful inspection and perfect fittings, however, this is frequently reversed.)
4. Householders are inconvenienced during repairs to mains, through having no storage cisterns.

(*b*) **Intermittent System.** The pipes are only filled with water at certain intervals, so that storage cisterns have to be provided to hold one or two days' supply.

Advantages.

1. As a rule less water is used than in the constant system. (It is doubtful, however, whether this is an advantage, especially in slum-dom.)
2. Fittings need not be so strong nor so perfect.
3. There is control over the water-supply in times of drought, or frost, so that waste or misuse can be guarded against.

Disadvantages.

1. Expensive cisterns have to be provided.
2. There is a risk of contamination through storage.
3. The alternate filling of the pipes with water and air favours corrosion of the pipes.
4. When they are empty there is less pressure in the water-pipes than in the air around, so that there is a danger of gas from leaky gas-pipes and ground-air being forced into them, to the detriment of the water which enters afterwards.
5. In the case of fire it may be difficult to secure a supply of water in time to prevent the conflagration spreading.

On comparing the relative advantages and disadvantages of the two systems, the constant system may be seen to be the better of the two under ordinary circumstances.

Impurities in Water.

I. Impurities at the source.

(1) *Rain water* may be contaminated by washing the air it falls through, but more by matters on the surface on which it falls, such as decaying leaves, soot, or other matters on the roofs of houses. It may also take *lead* from lead roofings and pipes, *zinc* from zinc or galvanised iron roofs; ammonia, nitrous and nitric acids from the air; sulphur compounds in towns, where much coal is burned.

(2) *Upland surface water.* This does not as a rule contain much dissolved matter, except in limestone or chalk districts, but in moorland districts it may be quite

discoloured with peaty material. Vegetable organic matter is far more prevalent than that of animal origin. There is an absence of ammonia, nitrites and nitrates beyond what is found in rain water.

(3) *Spring and well water.* The water in passing through the soil dissolves some ground-air which is richer in CO_2 than atmospheric air. This enables it to dissolve calcium carbonate and other mineral substances.

(4) *Shallow well water* may contain nitrites, nitrates, ammonia, and chlorine, or even organic matter from sewage soaking in from leaky drains and cesspools, and worse still it may contain disease germs from the excreta of persons suffering from such diseases as typhoid fever.

(5) *Deep well water* is free from suspended and organic matters, owing to the large amount of filtration it has undergone, but it may contain dissolved mineral matter as calcium and magnesium carbonates and sulphates, which makes it, as a rule, very hard.

(6) *River water* varies as to its impurities. In passing through cultivated land it may receive washings from the surface. Sewage or drainage and washings from mines and factories may pollute it at some points of its course, while other impurities will be present from the rain, spring, and other water which enters it.

II. Impurities acquired during transit to storage reservoir.

If the water is conveyed in closed pipes there is little risk of contamination. If it flows along open channels (*e.g.* rivers) surface washings, with leaves and branches of trees may find their way into it. Purification, however, may take place here:—(1) Suspended matter is allowed to subside; (2) bacteria in the water oxidise organic matter; (3) sunlight hinders the growth of pathogenic microbes.

These germs, whose natural habitat is in some organ of the body, are not in a suitable situation for growth, and, in time, lose their vitality.

III. Impurities of storage.

In the large storage reservoirs water-plants may be found growing on the surface. Water-rats, also, are

frequently found to exist there. The service reservoirs in towns are generally covered over so that there is not much danger of contamination.

Unless underground cisterns and tanks are made absolutely water-tight there is a danger of soakage from leaky drains and cesspools; while in metallic cisterns in the house lead or zinc may find its way into the water; and if the cistern be in an inaccessible part of the house, we may have dust, dead mice, etc., present. If the overflow pipe of the cistern passes into a soil-pipe, or into a sewer, there is a great risk of contamination with sewer gas.

IV. Impurities of distribution.

These may consist of metallic material from the pipes, while impure air and noxious gases may be forced in, if the pipes are occasionally empty.

(*a*) *Lead.* The waters which act *most* on lead are :—

(1) The purest, softest, and most highly oxygenated, *e.g.* rain water, and upland water.

(2) Water which contains organic matter and the products of its decomposition (nitrites and nitrates).

(3) Water containing free acid, *e.g.* peaty water from moorlands which frequently contains earthy acids owing to the action of bacteria which are found in peat.

(4) Water which contains chlorides. Sometimes a protective coating of lead carbonate is formed on the lead pipes, but this water dissolves the coating.

(*b*) Waters which act *least* on lead are :—

(1) Water which contains much mineral matter, as deep well water.

(2) Water with free carbonic acid (unless the CO_2 be in excess). A basic carbonate is formed and deposited on the pipe, but if the CO_2 be in excess this is re-dissolved.

(3) A little silica present in water has been known to protect the pipes, by forming an insoluble silicate of lead.

Note.—Water must remain for some time in the pipes to act on the lead; new pipes yield more lead than old ones; hot water dissolves more than cold water, and increased pressure increases the plumbo-solvent action. $\frac{1}{20}$ of a grain of lead per gallon makes the water dangerous.

Detection of Impurities.

An analysis of water may be (*a*) chemical, or (*b*) bacteriological. The former is the method which has been most frequently adopted, but the latter is now recognised as the more important, for if specific pathogenic micro-organisms are found in the water it is unhesitatingly condemned, while a chemical analysis shows at the best a *probability* only, that it is unsafe, in such cases. However, for *mineral impurities*, the chemical method is necessary, so both methods should be used and not one only.

(*a*) *Chemical examination.*

Lime is shown by a white precipitate forming when ammonium oxalate solution is added to the water.

Chlorine, add a solution of silver nitrate and dilute nitric acid. A white precipitate is formed.

Sulphuric acid, add a solution of barium chloride and a little nitric acid. A white precipitate is formed.

Ammonia, add Nessler's solution. A yellow colour or a yellow-brown-precipitate.

Lead or copper, add ammonium sulphide. A dark colour is produced, which does not disappear if hydrochloric acid be added after being concentrated by boiling. (This is best seen if the water be placed in a white porcelain basin.)

Iron, add a solution of potassium ferrocyanide, and of potassium ferri-cyanide with a little hydrochloric acid to two separate portions. We get a blue colour if iron be present.

Organic matter. Take a sample of the water and an equal quantity of distilled water, add to each the same amount of Condy's fluid. Leave to stand for some hours. Note the loss of colour in the water being tested as compared with the distilled water. The greater the loss of colour the greater the amount of organic matter present.

In a **Quantitative Chemical Analysis** the following particulars are obtained:—

1. Total solids (by evaporation of a measured quantity).
2. Volatile solids (residue after incineration of the total solids).
3. Total hardness (by amount of soap solution required to counteract the hardness).
4. Permanent hardness (hardness after boiling).
5. Ammonia (free). That which was present in the water before analysis.
6. Ammonia (albuminoid). That which is produced by the decomposition of nitrogeneous organic matter during the analysis.
7. Nitrites and nitrates.
8. Amount of oxidisable organic matter.
9. Amount of metallic substances present.

Organic matter present in water is generally decomposed into ammonia (NH_3) and other substances. The ammonia becomes partially oxidised to nitrous acid (HNO_2), or further oxidised to nitric acid (HNO_3). These acids combine with bases such as calcium, sodium, and potassium to form nitrites or nitrates.

The presence of ammonia may indicate *recent* fouling with organic matter (probably sewage); the presence of nitrites *less recent*, and nitrates at a *more remote period*. The presence of these in large quantities will be sufficient to condemn the water, for it *may* contain dangerous micro-organisms. Bacteriological examination alone settles this with certainty.

(*b*) Bacteriological Analysis.

The object of this is to find the number and kind of micro-organisms in water.

A measured quantity of water, after being well shaken in a sterilised bottle, is intimately mixed with fluid gelatine, which is then spread out in a thin layer on a glass-plate or in a Petri-dish (a shallow flat dish with a cover). The organisms form colonies in the gelatine which can then be counted and examined. For a qualitative examination some of the colonies which form on the gelatine are removed to other media and their growth observed. The microscopic appearance and manner of growth on various media indicate the kind of micro-organisms present.

They are generally divided into three groups:—

1. Those micro-organisms found in pure water.
2. Those common in sewage but rarely found in pure water.
3. Those which produce specific diseases in the body. This last class is the most important, the *Bacillus Typhosus* and the *Cholera Spirillum* being two examples.

Diseases caused by drinking Impure Water.

1. *Diarrhoea.* Suspended matter will cause this by mechanical irritation of the intestines. Water containing hydrogen sulphide will produce it, especially if organic matter be present. Some kinds of mineral matter, such as sulphate of magnesium (as at Epsom), will also give rise to it.

2. *Dysentery.* This is produced by drinking water which has been fouled by faecal discharges from dysenteric patients.

3. *Enteric Fever.* This is spread by drinking water, which has been fouled by the discharges from patients suffering from this disease.

4. *Cholera.* This also is spread by drinking water fouled by discharges from cholera patients. The drinking of

impure water will *predispose* to cholera or enteric fever, but will not *cause* the disease unless the specific germs be present.

5. *Dyspepsia* is sometimes caused by the presence of mineral matter.

6. *Parasitic diseases* may be produced by the eggs or embryos of parasites, being taken into the body with water.

7. *Metallic poisoning* may be due to lead, arsenic, copper, or zinc in water. The symptoms of lead-poisoning are:—(1) Indigestion, (2) abdominal pains or lead colic, (3) a blue line on the gums, (4) wrist drop, due to paralysis of muscles of the arm.

WATERPIPES AND CISTERNS.

The *mains* are generally made of cast iron with an internal protective coating, and are about 9 feet in length. The end of one fits into a socket on the end of the next. The joint may be made watertight by packing with deal wedges, and then with lead. This kind of joint allows for expansion and contraction through variations in temperature of water and earth. The mains are generally laid several feet below the surface.

The smaller pipes are made of iron or lead. Lead is convenient, as it can be carried round corners by simply bending, but is soluble in some water.

Methods of protecting pipes from corrosion.

1. *Barff's method.* Iron pipes are heated to a white heat—1200°F.—and while at that temperature, are exposed to the action of superheated steam; a protective oxide is formed on the iron.

2. *Angus Smith's method.* Pitch is distilled from coal tar until the naptha is removed, and then deodorised. A little linseed oil is added to it, and the mixture heated to about 310°F. The iron pipes, having been heated to a similar temperature, are immersed for some time in the pitch.

3. *Enamelled iron pipes.* White enamel is made by fusing glass with some zinc oxide; other colouring matter being used for glazes of other colours.

4. *Tin* is used as a protective coating for both lead and iron pipes, but is apt to crack, after which galvanic action is set up, and the lead, being more oxidisable than the zinc, is dissolved.

5. *Composite pipes* consist of a block-tin pipe enclosed in a lead pipe, the two being firmly connected together. If nitrates be present the tin may be eaten through.

Cisterns.

1. *Cisterns should be made of material which will not impart any injurious quality to the water. Slate* is the best material, if it is set in good Portland cement. No red or white lead should be used in making the joints, or it will enter the water, nor should common mortar be used as lime will be added, and the hardness thereby increased. *Lead* is not satisfactory because some waters dissolve it. *Zinc* and *galvanised iron* have been advocated but they are not so good as slate. Waters containing nitrates will dissolve zinc. *Iron* cisterns, if *enamelled* inside or *coated with good cement*, may be used.

2. *They should be easily accessible.* This is to facilitate frequent and regular inspection and cleansing.

3. *They should be covered in and ventilated.* This prevents the access of dust, dirt, and small animals, and keeps the air near it pure.

4. *The supply pipe for the water-closet should not pass direct from this cistern,* but a small flushing cistern should be provided. This is to prevent contamination of drinking water by gases from the W.C.

5. *The overflow pipe should open into the air* or into a waste pipe which opens into the air, and NOT into a soil-pipe.

Objections to the use of cisterns are, that the above conditions may not *all* be complied with; for water may be contaminated by (1) material from the cistern; (2) dust, dirt, and dead mice; or (3) sewer gases. Each cistern should have a *ball-tap* for automatically refilling when

emptied. A hollow ball, attached to a lever, floats on the surface of the water, and closes the inlet when full, and opens it when not full. See fig. 57 which shows one in a flushing cistern.

Amount of water required.

The daily amount per head of population may be taken to be about 30 gallons.

12 gallons for cooking, washing, drinking, etc.
8 gallons for flushing drains, sewers, etc.
10 gallons for trade uses, etc.

30 gallons.

The 12 gallons for domestic use is made up as follows:—

	gallons.
Cooking	·75
Drinking (tea, etc.)	·33
Ablution (including sponge bath) ..	5
Share of utensil and house washing..	3
Share of clothes washing	3
	12·08

The average for over 40 towns in 1888 was over 25 gallons per head. The average amount in London in 1899 was 28 gallons. Hospitals require almost double the amount used in houses, and some use *more* than double.

PRACTICAL WORK ON CHAPTER X.

1. *Filtration.* (*a*) Filter some water containing powdered charcoal through a filter paper, folded and placed in a funnel. This will illustrate the *mechanical* action of a filter, substances larger than the pores will not pass through.

(*b*) Mix salt and fine sand with water; filter the mixture; evaporate some of the filtrate, which will leave a residue of salt. This shows

that only suspended matter (the sand) is removed by filtration, while dissolved matter (the salt) passes through.

2. (*a*) Test water from various sources for mineral impurities, *e.g.* lead, or lime.

(*b*) Try the Condy's fluid test for water containing organic matter.

3. Pass CO_2 (prepared by the action of HCl on marble) through clear limewater. A white precipitate of carbonate of lime is formed. Continue to pass the gas, the precipitate dissolves. This shows how free CO_2 can enable water to dissolve chalk or limestone.

4. Make up some soap solution by thoroughly dissolving some soft soap in a mixture of 4 parts methylated spirit to 6 of distilled water, and then filtering. Dilute this or strengthen it as may be necessary so that 2·2 c.c. of it exactly give a permanent lather when shaken up with 50 c.c. of a solution of barium nitrate (which contains ·261 gm. of $Ba(NO_3)_2$ in 1 litre of water).

This soap solution can be used to estimate the hardness of water. 1 c.c. will neutralise 2·5 mgms. of calcium carbonate. Find how much of this soap solution is required to produce a permanent lather in 50 c.c. of a sample of water, and from this we find how much $CaCO_3$ is present in the water. The hardness is expressed in parts in 10,000, or in grains per gallon.

CHAPTER XI.

PREVENTABLE DISEASES.

The diseases included under the above heading are gradually increasing in number, and it is to be hoped that eventually all diseases will be grouped together as preventable. By the term preventable disease is meant one which, by taking proper precautious—*e.g.* the adoption of vaccination to avoid the occurrence of small pox—may be actually stamped out. An excellent illustration of the progress of disease prevention is given by the recent researches on the cause of malaria and its discovery. This disease, long regarded as inevitable in and unalienably associated with certain tropical districts, will, in all probability soon become either easily prevented or entirely unknown. The rapid reduction in the mortality from typhus fever in this country, and the virtual disappearance of small-pox from the whole of the German empire, are important proofs of the possibility of preventing diseases. Before classifying these diseases it is necessary to refer to the importance of abolishing any division of them into contagious and infectious—terms that should have long ago become obsolete as far as their use in classifying is concerned. The term "communicable" is now generally employed, and includes all diseases that have been previously classified either as contagious or infectious.

The most satisfactory classification of preventable diseases is their division into two classes, viz. :—

1. *Endemic diseases*, which may or may not be communicable from one person to another, and may be said to belong to the place and not to the people, and so are constantly present in certain

localities in consequence of unfavourable conditions and surroundings. Thus rheumatism occurs in damp localities, malaria is common in certain tropical countries where the necessary conditions prevail, and consumption may be induced by damp soil and deficient ventilation.

2. *Epidemic diseases*, on the other hand, are always communicable and spread with great rapidity from person to person, and from place to place. As these are the more important it is necessary to deal with them first.

Epidemic Diseases.

These include small-pox, scarlet fever, measles, whooping cough, diphtheria, chicken-pox, typhus fever, and enteric or typhoid fever, all of which have certain common characteristics, viz.:—

(1) They are all communicable from one person to another.

(2) Each disease has a definite duration.

(3) When a person becomes infected with either of these diseases no symptoms are at first produced. This interval which elapses between the time of infection and the appearance of the first sign or symptom of the disease is called the period of *incubation*. Then the ordinary symptoms of the disease appear and last for a certain time, during which the patient may die. If the individual survive the active period of the illness, recovery usually takes place.

(4) Their most remarkable characteristic is that an attack of either is rarely followed by another in the same individual, a fact that is expressed by saying that a more or less complete immunity from that disease is conferred for the rest of life.

Various doctrines have been held at different times as to the cause of disease, but only the most recent one—*the germ theory*—explains in anything like a satisfactory way the above characteristics. The germ theory was

suggested by observing the close analogy that exists between an attack of one of these diseases and the phenomena which are observed when some such an experiment as the following is performed. Take a large bottle and place in it some sugar and water. When the sugar has dissolved add a small quantity of yeast; then cork the bottle tightly, and let it stand in a warm place. At first nothing happens—this corresponds to the incubation stage of a disease. Then fermentation begins and results in the formation of alcohol and carbon dioxide—corresponding to the active period. Finally the fermentation stops, the alcohol and carbon dioxide having rendered the liquid incapable of being further acted upon by yeast, although there may be an abundance of sugar still left in the liquid. A further addition of yeast, moreover, produces no further change, so that there seems to be something here which is akin to the immunity produced in people who have had the disease. This obvious analogy between fermentation and infective disease processes has led to the term *zymotic* (from the Greek word meaning ferment) being applied to them.

Disease germs. The germ theory assumes that zymotic diseases are caused by microscopic living particles called germs or bacteria. These minute organisms are found to possess various shapes, and this affords the simplest means of classifying them.

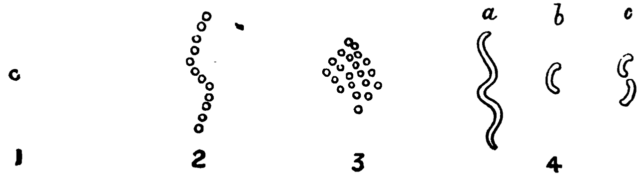


Fig. 82.—FORMS OF BACTERIA.
1, Coccus; 2, Strepto-cocci; 3, Staphylo-cocci; 4, *a*, Spirillum; *b* and *c*, comma-shaped spirilla.

(*a*) The *cocci*, or *micrococci*, are tiny round or oval shaped cells. If they are found to be arranged in strings or chains they are called *strepto-cocci*, and others, which are usually

arranged in irregular clusters like bunches of grapes, are called *staphylo-cocci*. These two kinds of cocci are frequently the cause of trouble in human beings. The *strepto-cocci* are generally found in spreading inflammations, erysipelatous conditions, and inflamed joints. They are also often the cause of acute inflammation of bones, and occasionally produce inflamed throats similiar to a diphtheritic condition.

The *staphylo-cocci* are commonly the cause of carbuncles, boils, and localised abscesses, and are also often found in cases of inflamed bone. Both kinds—strepto-cocci and staphylo-cocci—may be the cause of general blood poisoning.

(*b*) *Bacilli*. These consist of long or short cylindrical cells which may or may not be motile. Many important diseases have been conclusively proved to be caused by different bacilli. Thus the tubercle bacillus is always associated with phthisis or consumption; the anthrax bacillus is the cause of anthrax in animals and human beings; while the typhoid bacillus and the diphtheria bacillus are respectively the active agents in the production of typhoid fever and diphtheria. These various bacilli when properly stained are seen to have characteristic shapes—a fact which aids in their identification. A reference to fig. 83 will give the student some idea as to the characteristic appearance of some of these bacilli.

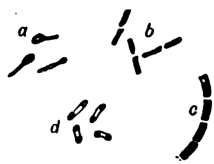


Fig. 83.
FORMS OF BACILLI.
a, Bacillus of Tetanus or Lock-jaw; *b*, Common Form; *c*, Bacillus of Anthrax (wool-sorter's disease); *d*, Bacilli showing bipolar staining.

(*c*) *Spirilla*. These consist of cylindrical cells more or less spiral or wavy. They may present the appearance of a slender wavy spiral thread, like the spirillum of relapsing fever (fig. 82, No. 4*a*), or they may look like a simple curved rod, like the "comma" shaped spirillum of cholera.

How germs are conveyed. When germs have once been introduced into the body they grow and multiply enormously. In most cases it is very likely that infectious

material is cast off from the body from the commencement to the end of the disease, so that the patient remains a possible source of infection for a considerable time. Germs differ to some extent in the way that they are most liable to be spread from one place to another. The commonest methods are:—

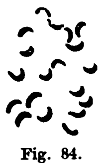


Fig. 84. CHOLERA SPIRILLA.

(*a*) *By air*. The germs of whooping cough, scarlet fever, measles, small-pox, chicken-pox, diphtheria, tuberculosis, mumps, influenza, and plague, seem to be capable of being carried in the air from place to place. The result is that inhalation is probably by far the most frequent means of communication of these diseases. In camps, enteric or typhoid fever is frequently spread by dried excreta of typhoid cases becoming pulverised and floating about in the air, ultimately finding its way into the human body either with the breath or swallowed with the dust. This, also, probably accounts for the occasional spread of typhoid fever in hospital wards, where due attention is not paid to the disinfection and careful handling of all soiled linen. In some diseases—typhus fever, small-pox, and diphtheria in particular—the breath of the patient appears to be specially infectious.

(*b*) *By water* (and food). The two most important diseases usually spread by infected water are typhoid fever and cholera. Dysentery and some forms of diarrhoea may also be conveyed in the same way. Infected milk may probably spread tuberculosis, and this is generally supposed to be the chief cause of "consumption of the bowels," but whether this is true or not appears to be still a disputed point. Epidemics of scarlet fever have undoubtedly been proved to be connected with infected milk.

(*c*) *By clothes*, etc. Disease germs may lie dormant in the clothes or furniture of the sick room for long periods, causing infected books, clothes, toys, and furniture to undoubtedly play a very important part in the spread of disease. Scarlet fever and small-pox appear to be very often communicated in this way.

(*d*) *By living creatures.* Flies are probably very active agents in the conveyance of bacteria from one spot to another, and it is extremely likely that they may have been the cause of many of the outbreaks of typhoid fever which have not definitely been traced to a previous case. It is easy to imagine that all kinds of diseases are spread long distances by this means. The communication of disease by means of birds or domestic animals is also another possibility.

At first sight it would appear that, as we seem to be surrounded on every hand by all kinds of bacteria which are capable of producing disease, every one of us must eventually suffer from almost every known disease. Practical experience, however, shows that this is not the case, and the explanation lies in the fact that a healthy individual can usually resist the attacks of these germs, and probably disposes of them by a process similar to digestion. Two people may be exposed to infection at the same time and under precisely similar circumstances, yet one may contract the disease while the other escapes. This is explained by saying that the one is more *susceptible* than the other to the illness in question, which means that the vital actions of the second person successfully opposed the invasion of the bacteria while the first could not offer sufficient resistance to their multiplication in the body. The susceptibility to infection, as a general rule, decreases with advancing age, and depends also upon the state of health of the individual, hereditary predisposition, and individual or family idiosyncrasy.

The common practice of exposing children to infection, on the pretext that, sooner or later, they will be bound to have certain diseases, *e.g.* measles, whooping cough, and scarlet fever, is nothing less than criminal. It should be remembered that a mild case in one child may give rise to a fatal case in another, and that one attack of the above ailments does not necessarily afford protection from a second; also a large number of children escape them altogether, and as the child gets older the liability to attack and the fatality both diminish.

Results of Infection. These have already received some

attention. As a rule the entry of the germs is followed by a period of *incubation*, during which no changes are manifest, and which varies from 2 or 3 to 25 days, being generally fairly constant for each particular disease. During this period the germs rapidly multiply in the body, and eventually the second stage, or *period of invasion* is reached, which is accompanied by the symptoms peculiar to the ailment in question. Many of these symptoms are undoubtedly produced by a poison which is manufactured by the germs. This poison is called a *toxine*. The *duration* of many diseases is often strictly limited. Thus typhus, scarletina, measles, and small-pox have a fairly definite duration. If the patient survives, the end of the disease is probably brought about by the influence of a material called *anti-toxine*, which the cells of the patient's body have manufactured, and which prevents further development. This process may also be somewhat analogous to the destruction of animals by means of poisons manufactured by themselves if they are shut up in a closed room. More recent experiments, however, tend to show that the anti-toxine is manufactured by the tissues of the patient, and not by the bacteria. However this may be brought about is not yet fully known, but there is no doubt that in the case of diphtheria, typhoid, cholera, pneumonia, etc., certain substances appear in the blood which are antagonistic to the toxine and to the vital activity of the germs.

Prevention of Infection.

The spread of infectious diseases is prevented by carefully and thoroughly carrying out various instructions, and the adoption of different precautions such as are grouped together as follows:—

1. The separation of the sick from the healthy, or *isolation*.
2. The separation of persons who have been exposed to infection, or *quarantine*.
3. The destruction of the disease germs, or *disinfection*.

4. The acquirement by the healthy of such a condition as to render them insusceptible to the influence of the germs, *i.e.* the production of *immunity*.
5. The immediate intimation of the occurrence of every case of infectious disease to the medical officer of health, or *notification*.

Isolation. The best method of isolating a case of infectious disease is to send the patient to an isolation hospital. In many cases, however, this is quite impossible, and so the patient has to be treated at home. When this is done the following conditions must be strictly observed:—

(*a*) The sick-room should be either at the top of the house or, better still, in a detached wing; the windows must be such as will afford ample ventilation, and there must be a fire-place in which a fire is kept continually burning.

(*b*) The common practice of hanging a large sheet, kept moist with a solution of carbolic acid or any other disinfectant, outside the door of the sick room is probably of no manner of use except, perhaps, to impress the people of the house with the fact that every precaution should be taken to prevent any contamination from coming out. Nor is any useful purpose served by placing in the room or about the house vessels containing Condy's fluid or any other liquid.

(*c*) All unnecessary furniture or articles to which contagion may adhere should be removed from the room. No bed curtains, window curtains, or carpets are permissible, and only such books, papers, or toys should be allowed as may be afterwards burned.

(*d*) The nurses or attendants should be, as far as possible, those who are protected by a previous illness or by other means, and no one else should be allowed access to the room.

(e) In the room the nurse should wear a simple linen dress which can be readily disinfected and washed. Before going to any other part of the house she should change her outer garments and wash her face, hands, and arms in some disinfectant.

(f) Only the nurse should be allowed to take anything into the room. All food, coal, crockery, knives, etc., must be left outside, whence they may be fetched by the nurse.

(g) Nothing must be taken from the room without previous disinfection. All crockery must be washed in some disinfectant inside before it is taken outside. Similarly all excreta from the sick should be at once disinfected and then removed, and any soiled linen and clothes must be treated in the same way. Discharges from the eyes, ears, nose, etc., should be wiped away with pieces of clean rag and burned immediately after use. Any superfluous food should be burned in the fire or some disinfectant added to it.

Isolation must be commenced as soon as the case is diagnosed as infectious, and must be continued until the danger from infection has ceased. This generally occurs in 8 weeks for whooping-cough; 7 weeks for small-pox and scarlet fever, or until the skin is quite free from scales or scabs; and 4 weeks for diphtheria, measles, typhoid fever, and mumps.

Quarantine. The meaning of the term *incubation* has already been explained, so it will be readily understood that there may be numbers of apparently healthy individuals in a community who are already infected, but in whom no symptoms have as yet appeared. To prevent this it is advisable that all persons who are known to have been in contact with an infectious case should be isolated and kept under observation for a period which varies according to the disease under consideration. This method

is particularly valuable in preventing the spread of small-pox in a district. When a case is notified it should be removed at once to an isolation hospital, and all possible effort should be directed to discover any individuals who may have been infected. These should be held in quarantine until all possibility of their having contracted the disease has gone.

Disinfection. The disinfection of anything, whether it be a towel, plate, spoon, or a room, really means the destruction of all bacterial life adhering to it. Any substance or process which is capable of achieving this end is called a *disinfectant* or *germicide*, and these terms should be absolutely restricted to such substances. It is probable that upon no subject in connection with disease is there denser ignorance than upon that of disinfection, and the word disinfectant is used broadly to denote deodorants and antiseptics as well as true disinfectants or germicides. A *deodorant*, as eau de Cologne, camphor, tobacco smoke, carbon, etc., merely mask a bad smell and have *no action whatever* upon the germs which are the cause of the bad smelling gases. The term *antiseptic* should be applied to those substances which *prevent the development and increase* of germs, *e.g.* Condy's fluid, iodoform, common salt, boracic acid, or a dilute solution of some disinfectant like carbolic acid. A disinfectant, on the other hand, must not only arrest the growth of, but absolutely destroy. disease germs. The substances most often employed as disinfectants are.—

(*a*) *Condy's fluid* is a popular disinfecting liquid, but of very little utility as a germicide or true disinfectant. Its chief use is as a deodoriser and antiseptic, being particularly beneficial in cleansing and sweetening foul discharges from ulcers and wounds, and for bad throats.

(*b*) *Carbolic acid* in a diluted condition, such as 1 per cent. solution, is an antiseptic, but in 5 per cent. solutions it acts as a fairly satisfactory disinfectant, being sometimes used to disinfect the excreta of typhoid patients. When used for this purpose it should be remembered to leave the carbolic acid in contact with the stools, after mixing,

for at least half an hour. Carbolic powders—so called—have very little germicidal power as a rule.

(*c*) *Corrosive sublimate* is a far more active disinfectant than carbolic acid, and is a powerful germicide even in such dilute solutions as 1 in 1000 or $\frac{1}{10}$ per cent. It also has the advantage of not injuring wood, varnish, paint, plaster, cotton or linen. It may be made by dissolving half an ounce of corrosive sublimate (perchloride of mercury) in one ounce of hydrochloric acid and a pint of boiling water. The solution is then diluted with water up to 3 gallons, and is coloured by the addition of 5 grains of aniline blue. It must be kept in earthenware or wooden vessels. For disinfecting the stools of cholera or typhoid patients this substance is by far the most satisfactory.

(*d*) *Formalin* is a 40 per cent. solution of formic aldehyde. Used in a 1 or 2 per cent. strength it is an active disinfectant, and is more potent and cheaper than carbolic acid. The gaseous *formaldehyd* is now highly recommended for room disinfection. It is non-corrosive and does not attack metals. The most convenient method of generating this gas in a room is by a specially constructed lamp which burns methylated spirit, and above the flame of which is suspended a metal cup containing a substance called *paraform*. Formic aldehyde is produced in this way, and being more diffusible than sulphur dioxide, it is more satisfactory. A preliminary spraying of the room with a 1 per cent. solution of formic aldehyde greatly adds to the efficiency of the process.

(*e*) *Chlorine* is one of the gaseous disinfectants. It is conveniently prepared by mixing together 1 lb. of common salt and 1 lb. of black oxide of manganese in a basin, and then adding 2 lbs. of oil of vitriol. Dissolved in water, 1 per cent., it has been used for washing the walls of rooms, and a solution of sodium hypochlorite containing 1 per cent. of active chlorine has given good results.

(*f*) *Sulphur dioxide* is another gaseous disinfectant which is extensively used for the disinfection of rooms. The common plan is to prepare it by burning sulphur, broken into small pieces, in an iron vessel. The quantity of sulphur that should be used is 1½-3 lbs. per 1000 cubic

feet of room space. The vessel containing the sulphur should be supported upon two bricks standing in a tray containing water. To facilitate the firing of the sulphur a loose cone of paper should be placed in the middle of the mass, and this is moistened with a little methylated spirit, which readily burns and ignites the surrounding sulphur. Sulphur dioxide is usually regarded as an efficient disinfectant.

(*g*) *Heat.* Burning is the most efficient method of disinfection, and all rags which have been used for receiving discharges from the nose or mouth should be at once placed upon the fire. Old mattresses, pillows, etc., should be saturated with paraffin and burned if they are not required for further use. Boiling may be regarded as an efficient means of disinfection for bed and body linen especially if preceded by immersion in corrosive sublimate solution.

Disinfection by *hot air* does not give satisfactory results and is falling into disuse. Hot dry air requires a long time to penetrate into bulky articles such as mattresses, and is only rendered capable of killing all bacteria by raising the temperature to such a degree as would scorch and spoil many materials.

The use of dry heat is necessary in the case of leather articles and bound books, as these articles are spoiled by steam, but with these exceptions the disinfection should be carried out by steam.

Steam is by far the most satisfactory disinfecting agent for beds, mattresses, pillows, blankets, etc., chiefly on account of the rapidity with which it penetrates them, and to some extent, because it kills bacteria more quickly. The reason why steam penetrates so rapidly is easily understood when one considers that as it condenses into water it has its volume reduced 1600 times. As the steam, therefore, passes into the interstices of a cold body it condenses to water, gives up its enormous latent heat instantaneously, and shrinks to $\frac{1}{1600}$ of its original volume, thus creating a partial vacuum which is immediately filled by fresh steam, so that the whole mass is rapidly permeated. As a result of experiments it has been found that hot air at about

250° F. will only raise the temperature of a thermometer placed beneath 8 layers of blankets to about 180° F. in 4 hours, while steam at the same or lower temperature will raise it to 218° F. in 15 minutes under the same conditions.

The steam employed may be either saturated or superheated. The distinction between these terms is important, but often mis-stated. By *saturated steam* is meant steam in such a condition that the slightest cooling will cause it to condense. The temperature of such steam may vary considerably, and depends, in fact, upon the pressure at which it is generated. By increasing the pressure, steam at temperatures above 212° F. can be obtained but it always remains saturated as long as the pressure continues constant. *Superheated steam*, on the other hand, is unsaturated, and a slight decrease in temperature will not cause it to condense. Superheated steam would be obtained if, for instance, the saturated steam (at 212° F.) from an ordinary kettle were passed through a tube the temperature of which was 250° F. In this case steam would be obtained at 250° F. and it is called superheated because it will not condense until it is cooled below 212° F. again. By boiling water under considerable pressure it could be obtained at 250° F. but this would be saturated because any small decrease in its temperature would cause it to condense. As explained above, this readiness to condense is an important factor in the usefulness of steam as a disinfectant, and it is obvious that the saturated form is immensely superior to superheated steam for this purpose.

Disinfecting Processes.

Disinfection of discharges and excreta. The excreta of cholera and typhoid patients should be immediately disinfected by strong carbolic acid or a 1 in 100 solution of corrosive sublimate. They should not be thrown into any fixed privy receptacle and, above all, they must never be cast where they can run or soak into sources of drinking water. Discharges from eyes, nose, and mouth should be wiped away with clean rags which must be immediately burnt.

Disinfection of clothing, etc. Linen and cotton clothes

may be disinfected by prolonged soaking in 1 in 20 carbolic acid solution, or in 1 in 1000 corrosive sublimate solution. Woollen materials, blankets, pillows, beds, mattresses, etc., should be disinfected by the local sanitary authority by means of saturated steam.

Disinfection of the patient. After the patient has recovered, and before he mixes with his friends, he should have several warm baths, and be rubbed with carbolic soap. In scarlet fever, where extensive shedding of the skin occurs, special treatment is required. During desquamation the body should be washed, night and morning, with soap and warm water, and in the intervals it should be smeared with carbolic oil (made by mixing one part of carbolic acid, three of eucalyptus oil, and sixty parts of olive or almond oil) to prevent the particles being carried off into the atmosphere.

Disinfection of the Room. It is perhaps still necessary to state that any attempt to disinfect a room as long as the patient remains in it is ridiculous. After the patient has left the room in which the illness has occurred it requires to be thoroughly disinfected before it is occupied by others. All cupboards and drawers should be opened and the walls and floor made wet by sprinkling water. The chimney should be stopped up and the chinks of the windows pasted over with strips of brown paper. The sulphur is then lighted, and the door finally sealed by brown paper and paste. A minimum of 1½ lb. of sulphur should be used for each 1000 cubic feet of air space, and the use of 2 or 3 lbs. is advocated by some authorities. The room should now be left for 24 hours, if possible. At the end of that time the doors and windows should be thrown widely open for several hours, so that the room may be thoroughly flushed with fresh air—a part of the process which is at least as important as the burning of the sulphur. The furniture and all movable articles should be carried into the open air and thoroughly brushed and dusted. It should be remembered that bronze, gilt, and copper surfaces are tarnished by the sulphur fumes, and it is advisable to remove all bright metallic articles. The paper should be stripped off the

walls and burnt, the ceiling and walls limewashed, and the floor and woodwork scrubbed with carbolic soap or sanitas. Such is the plan generally advised, and it is adopted by practically all sanitary authorities. If coupled with the thorough disinfection of bedding, and all possibly contaminated clothing it is probably fairly efficacious, but if it is the only disinfecting process that is carried out it obviously cannot have much effect in preventing the spread of disease.

Immunity. Persons who are insusceptible to a particular disease are said to be immune, or to possess immunity. It is convenient to divide immunity into two kinds, (*a*) natural, and (*b*) acquired.

(*a*) *Natural Immunity.* The immunity of negroes towards yellow fever may be given as an illustration of this. No satisfactory explanation has yet been offered for such phenomena, but it seems to depend upon either the insusceptibility of some individuals to the toxines produced by certain bacteria, or to special bactericidal powers possessed by the tissues or fluids of these persons. It is a well-known fact that different animals have different degrees of resistance or non-susceptibility to toxines and other poisons. The common fowl, for instance, is unaffected by a large dose of the toxine produced by the tetanus bacillus, while a pigeon is able to resist a dose of morphia that would kill a human being. On the other hand, the immunity may be due to phagocytoses or the destruction of bacteria by the white corpuscles or leucocytes and other cells of the body; and another possibility is suggested by the fact that blood serum is capable of destroying certain bacteria.

(*b*) *Acquired Immunity* is that which is imparted in one or more ways to individuals previously susceptible. The commonest cause of this kind of immunity towards an infectious disease is the fact that the individual has already suffered from an attack of it. There are but few exceptions to the rule that scarlet fever, small-pox, chicken-pox, measles, and other such illnesses, do not occur a second time in the same patient. Probably no one explanation will suffice for all cases of this kind, but the immunity is,

in all probability, closely connected with the manufacture of antitoxines by the tissues of the body, and also of antitoxic bodies by the bacteria themselves.

Immunity to some diseases may be acquired by inoculation with the poison after it has been so modified by being passed through some suitable animal, that it produces only a trifling ailment, and yet affords an immunity which is practically equal to that given by an ordinary attack.

Fig. 85.—How Serums are made: Injecting Toxin.
From Messrs. Parke Davis and Co.'s "Therapeutic Notes."

After the strength of the toxin has been determined, treatment of the horses is begun. The initial doses of toxin are very small, but these are gradually increased until the animals withstand enormous doses. They are then known to be immune to the toxin, and their blood contains large amounts of antitoxine. (Diphtheria.)

The most familiar of these methods is *vaccination*, which consists in the inoculation of cow-pox, derived from the calf. In all probability the immunity from small-pox conferred by vaccination is due to the fact that cow-pox is really a profoundly modified form of small-pox.

A similar method of conferring immunity is by successive inoculations with a weakened or attenuated form of the disease after it has been passed through various animals. Pasteur's method of preventing hydrophobia

consists in first inoculating the patient with the toxines of the disease after it has been passed through successive rabbits, and the poison further modified by exposure to dry air. Successive inoculations are then made with less attenuated forms until at last an inoculation is made—without any ill-effect—with material which would undoubtedly set up symptoms of hydrophobia in persons who

Fig. 86.—How Serums are made: Abstraction of Blood.
(From Messrs. Parke, Davis and Co's. "Therapeutic Notes.")

In the abstraction of blood a narrow tube is passed into a vein in the neck. The blood is collected in large tubes, which are then closed with cotton wool and set aside until the clot separates.

had not been through the previous course. The individual is then incapable of contracting rabies.

Quite a different method of securing immunity is by the subcutaneous injection of *antitoxines*, a mode of treatment which has been adopted in cases of tetanus (lock-jaw), diphtheria, and snake-bite with brilliant results. For the manufacture of the antitoxin of diphtheria a horse is injected with gradually increasing doses of the toxines produced by the diphtheria bacilli. As a result, the horse acquires a high degree of resistance to these poisons so that towards the end a dose may be safely

injected which would probably have been fatal in the beginning. The blood serum of this horse is now found to have the remarkable property of neutralising or counteracting the effects of the toxine on other animals. The active principle of this serum is called the antitoxine. The effect of injecting such an antitoxine into a patient suffering from diphtheria is to neutralise the effect of

Fig. 87.—How Serums are made: Blood-Tubes showing proportion of Clot and Serum.
(Parke, Davis and Co.)
When the clot has formed the serum rises to the top. The antitoxin is contained in the serum.

the toxines which are being produced by the diphtheria bacilli and which cause all the ill-effects of the disease. If injected within the first three days of the illness it appears to prevent the occurrence of all the subsequent symptoms. The essential difference between this method and the previous one is that in this method the patient has the benefit of antitoxines which have been manufactured by the horse or some other animal, while in the previous method he gradually manufactures his own antitoxine.

Notification. The compulsory notification by medical men of infectious disease occurring in their practice has undoubtedly proved of very great benefit in preventing epidemics. At the same time the full benefit from this law cannot be expected unless means are provided for the effectual isolation of such cases, and also for the complete disinfection of all bedding and clothes. The Infectious Diseases Notification Act, 1889, with the Infectious Diseases (Notification) Extension Act, 1899, compels medical practitioners to notify the following diseases:—small-pox, cholera, diphtheria, membranous croup, erysipelas, scarlet fever, typhus fever, typhoid fever, relapsing fever, and puerperal fever. Moreover, any local sanitary authority has the power to add other diseases, notably measles and chicken-pox, to this list.

The above methods—isolation, disinfection, quarantine, notification, and the production of immunity—are the modern means of battling with the spread of infectious diseases. As a result even of their present imperfect adoption there has been a very great decrease in the mortality from such diseases. All, in fact, have steadily declined owing to the introduction of the above measures, except whooping-cough, which appears to be independent of any sanitary precautions, and measles, which has increased in large towns. The apparent increase in diphtheria is probably due partly to improved methods of diagnosis.

Details of Various Diseases.

Small-pox is a disease to which an immense amount of study has been devoted, owing, on the one hand, to the havoc it formerly wrought among European and Asiatic nations—a havoc which, at the present day, is difficult to realise—and on the other hand to the bitter controversies which have arisen in connection with the method of acquiring immunity against it introduced by Jenner. Before the introduction of vaccination the epidemics of small-pox occurred every three years, or oftener, and were attended by enormous fatalities, also loss of eyesight and an amount of disfigurement that is

difficult to realise now. The incubation period of small-pox is about 12 days, and it is infectious from the very commencement to the very end of the disease. The secretions of the nose, throat, and mouth, as well as the contents of the pustules or pocks are infectious. Probably the infective matter is given off very abundantly as a fine dust when the pocks have dried and are beginning to become detached, causing small-pox to be more widely propagated than any other disease.

Immunity against small-pox may be obtained in one of three ways:—

(*a*) By natural small-pox;
(*b*) By inoculated small-pox;
(*c*) By vaccination.

The amount of immunity conferred by a previous attack depends upon the severity of the illness, a severe attack giving a more lasting protection than a mild one.

Inoculation of the disease itself has been practised in India, China, and the East generally for a great number of years. The practice was introduced into England about 1723 and became very general about the latter half of the eighteenth century. The fatality of the disease so imparted was found to be much less than that of natural small-pox, 2 or 3 per cent. of the cases ending fatally instead of 20 or 30 per cent. This method was, however, rightly abolished as it increased the number of cases from which infection could spread.

A discussion of *vaccination* is beyond the scope of this book. The theory of the immunity derived from it has already been mentioned. It is found as a rule that the production of one scar by vaccination affords immunity for one year, while four good scars confers immunity for 10 or more years. Moreover it can be proved that the fatality of the disease is inversely proportional to the number of marks or scars, the mortality among persons with one mark being 6·2 per cent.; with two marks 5·8 per cent.; with three marks 3·7 per cent.; and with four marks 2·2 per cent. Re-vaccination at the age of 12 to 14, if properly performed, undoubtedly confers almost absolute immunity

for the remainder of life, and in countries where re-vaccination is compulsory the disease is practically unknown.

As the incubation of vaccination is 8 days as compared with 12 days for small-pox, it is possible to render a person immune after he has actually contracted small-pox. Thus if a person is exposed to infection on a certain day and be vaccinated either at once or during the following two days the development of small-pox will be anticipated by the vaccination. Vaccination on the fourth day *may* prevent the development of small-pox or, more likely, cause the case to be a very mild one.

The only argument of anti-vaccinators that is worth any attention at all is the one that attributes the reduction of small-pox to improved sanitation. This is conclusively proved to be false on the following grounds:—

(1) Before vaccination was compulsory, small-pox was a disease of childhood, while it is now transferred to later periods of life. The obvious explanation is that vaccination protects the infant population from small-pox, but that as the immunity conferred gradually passes away, the susceptibility to infection increases with age.

(2) Most conclusive evidence of the intimate relationship that exists between re-vaccination and immunity, is shown by the insusceptibility enjoyed by re-vaccinated postmen and nurses. The re-vaccinated nurses at the Leicester Small-pox Hospital escaped, while those who refused vaccination contracted the disease. Also the statistics of the epidemic of 1900-1901 are equally convincing as to the efficiency of vaccination.

(3) The fatality among vaccinated cases is very much less than among the unvaccinated.

(4) Among the small-pox cases who have been previously vaccinated it is found that the greater the number of vaccination marks there are, the less is the mortality due to the disease.

(5) In epidemics it is a common experience to find that *in the same house* the disease will attack the unvaccinated inmates, and pass by those who have been vaccinated. If a vaccinated and an unvaccinated person contract the disease together there is a conspicuous difference in the severity of the two cases.

(6) In Germany where vaccination *and* re-vaccination are compulsory small-pox has been almost stamped out, in fact for many years there has not been a case of purely native origin.

The increased number of small-pox cases which usually occur in the neighbourhood of small-pox hospitals afford evidence as to the possibility of this disease being conveyed by air for a considerable distance. Probably many of these cases have been due to the laxity of the regulations controlling the access of tradesmen and others to the premises, but this can hardly be urged as a cause in the case of the floating hospitals in the Thames, where there cannot be any question of the infection being conveyed outside by nurses, attendants, ambulances, etc., and yet it is conclusively shown that the districts nearer the ships had a greater number of cases than those farther away, and also that the direction of infection was that of the prevailing wind. The conclusion that one must draw is obviously that the aggregation of a large number of acute cases of small-pox is fraught with serious danger to the public, and the question naturally arises whether the risk to the lives of the patients themselves is increased by treatment in a strongly infected atmosphere. It is indeed fortunate that other methods for controlling the terrible disease are available, namely, vaccination and re-vaccination. Now that it is being realised that a definite danger arises from isolation the last plank is removed from the platform of the anti-vaccination agitator. Without wishing to decry the secondary advantages to be derived from improved sanitary conditions and the provision of hospital accommodation, it is increasingly evident that small-pox will never be eradicated until the community

is protected by compulsory vaccination and re-vaccination.

Chicken-pox is a disease of childhood but may affect people of any age. It is highly infectious, being probably transmitted by the breath of affected persons. As the disease is usually trivial it is not usual to take any special precautions as to disinfection.

Scarlet fever. The incubation period of scarlet fever is variable, being usually 3 or 4 days, and the disease is probably highly infectious from its commencement. In the earlier stages infection is spread mainly by the breath and the secretions of the nose, mouth, and throat, and later on a possible cause may be the scales of desquamating skin which are particularly liable to adhere to clothing and to lie latent for an indefinite period. The spread of scarlet fever by the milk supply has already been referred to in dealing with the subject of milk. There is a *possibility* that cows may suffer from a disease akin to scarlet fever and so yield an infected milk, but the chief danger arises when a case of scarlet fever occurs at a dairy and the milk becomes infected by the direct absorption of bacteria from that case. The means of preventing the spread of scarlet fever will therefore include, in addition to notification, isolation, disinfection, etc., an investigation as to the possibility of there being a contaminated milk supply.

The contagion of scarlet fever, unlike that of small-pox, does not appear to be capable of travelling long distances by the atmosphere. The commonest cause of its spread is carelessness in allowing convalescent patients to mix with other people before the desquamation or "peeling" of the skin has completely finished. The pieces of skin may not actually be infective, but it is a fairly good rule that the case is infective as long as there is any trace of desquamation, or any discharge from the ears. Another cause is the occurrence of very mild cases that are not recognised but which are capable of infecting others with a much more severe type of the disease.

Measles produces a very high death rate among children, but is not necessarily so fatal as it appears, most of the

deaths being due to bronchitis and pneumonia, which so often either complicate or follow an attack of measles and are frequently caused by neglect and exposure to cold. The incubation period is usually about 10 days, and its rapid spread is undoubtedly due to the fact that it is highly infectious before the rash appears, while its symptoms cannot possibly be distinguished from common catarrh. The disease is so universal in this country that few escape from it. The contagion has very small powers of resistance and cannot retain its vitality long, so that the ordinary processes of disinfection are quite sufficient.

The increase in the prevalence of measles during recent years is usually attributed to:—

(*a*) The crowding together of children in schools;
(*b*) The increase in town populations;
(*c*) The impossibility of recognising the disease before it becomes infective.

If an outbreak of measles occurs in a boarding school, the cases should be at once isolated, and all scholars who have been in the same dormitory during the previous week, or sat next to them in class-rooms during that time, should be placed in quarantine. If the latter procedure cannot be carried out, the next best thing is to isolate all scholars who show any signs whatever of an ordinary cold.

During an epidemic in a district the following precautions should be taken:—

(1) Children from infected houses should not be allowed to attend school.
(2) Scholars who appear to be suffering from a cold should be sent home.
(3) All absentees should be visited in order to ascertain the reason of their non-attendance.
(4) In rural districts the closure of schools during an epidemic is desirable, but in towns the advantages of this proceeding are doubtful. During the closure the school should be thoroughly disinfected.

German measles is an infectious disease which has symptoms bearing some resemblance to both measles and scarlet fever. It is quite a distinct disease. It usually has a long incubation period of about 16 days and is very infective. The illness is generally mild and the disease is not common.

Whooping-cough is a disease which may attack people at any age, though it is commoner and more fatal among infants than among older children and adults. Its incubation is about 8 days. The case should be at once isolated, and the secretions from the mouth, nose, and throat, and also the vomit, should be treated as infectious. After the illness the clothes and the room must be disinfected. The duration of the attack averages 6 weeks, but it may be as short as three, or prolonged for months. It is probably infectious by the breath before there is any cough. Whooping-cough is now the most fatal of all the infectious complaints of children under 5 years of age. The greatest number of cases occur during March and April. An epidemic of whooping-cough often follows an epidemic of measles.

Mumps frequently occurs in epidemics during cold and wet weather, giving rise to little, if any, mortality. The outbreak is often associated with an epidemic of measles. The disease has an incubation period of over a fortnight, and it frequently attacks children or young adults. From 3 to 4 weeks isolation is necessary.

Diphtheria. During the last 20 or 30 years there has been a progressive increase in the rate of mortality from diphtheria in England and Wales, and the increase is chiefly in densely populated districts. This increase is all the more peculiar when it is noted that it has coincided, in point of time, not only with the improvement of the sanitation of these districts as regards water supply, removal of refuse, drainage, and sewage, but also with a continuous and marked diminution of the rate of mortality from the group of zymotic diseases (including diphtheria). Cases of diphtheria are particularly liable to appear in rural districts independently of any pre-existing case. This usually happens in damp and badly-drained localities.

There is also reason to believe that in some cases epidemics of diphtheria are preceded by the prevalence of sore throats which do not in the first few cases present any of the ordinary symptoms of diphtheria, but which increase in severity until they assume a definite type which is indistinguishable from diphtheria. A bacteriological examination of the secretion from such throats would probably show that they were really mild cases of diphtheria, and were all caused by the characteristic bacillus of diphtheria.

Abundant evidence appears to be available to show that diphtheria may be conveyed by milk, and this infectivity of the milk seems to have been due, in some cases, to some disease in the cow. Domestic animals, particularly cats, are liable to a form of diphtheria which is undoubtedly responsible for a large number of cases. The increase in the number of cases occurring in towns is probably due to the system of compulsory education which now prevails, mild cases being able to attend school and infect other scholars, who, in their turn, take it to all parts of the locality. Part of the increase is, however, undoubtedly due to the improved facilities for the correct diagnosis of the mild cases on bacteriological grounds.

The incubation period of diphtheria averages between 2 and 5 days. The greatest number of cases and the maximum mortality occur between the ages of 3 and 12. Cases should, of course, be isolated, and all discharges from the nose and throat, as well as clothes and bedding, must be disinfected. When an epidemic occurs the milk supplies should be investigated, and the usual attention paid to schools and school attendances as described under measles. All children suffering from sore throat should be sent home. The use of diphtheria antitoxine has a remarkable effect in cutting short the symptoms, and it probably reduces the infectivity.

Enteric Fever—or typhoid fever—is essentially a disease of contaminated water or food. Such contamination can only be produced by the bowel discharges of a previous case. For this reason the most stringent precautions should be taken to ensure the thorough disinfection of these in every case. The best ways of doing this have been

described under "disinfection," and these precautions must be continued during convalescence until the stools have resumed their natural appearance.

The incubation period is variable, averaging about 12 days, and the disease is most prevalent during youth and adolescence. The commonest causes are:—

1. Contamination of the water supply by sewage containing the evacuations of a typhoid patient. In country districts this may be produced by cesspool soakage into shallow wells, and in towns by the contamination of a reservoir, or the pollution of water in a cistern through its overflow pipe communicating with a drain, and the infection of rivers by sewage.
2. The contamination of food by polluted water. This is particularly liable to occur with milk which is adulterated with infected water, or which has been put into cans containing small quantities of the water that was used to wash them out. It is now established that the infection of enteric fever may be conveyed in shell fish, more especially in oysters, mussels, and cockles, which are collected from beds where the water is liable to extensive pollution from sewage.
3. Direct infection from a patient. The chief cause of direct infection from a typhoid patient is probably a lack of care on the part of the attendants and nurses in keeping their hands scrupulously clean and thoroughly disinfected before taking food, and after attending to the patient in any way. All stains on bed linen should be at once covered with a 1 per cent. solution of corrosive sublimate.

The chief points to be observed, therefore, in order to prevent the spread of typhoid in a district are:—

(*a*) Care on the part of the attendants on cases to prevent them being infected.

(*b*) Complete disinfection of the bowel discharges and the urine.

(*c*) An inquiry into the cause of the outbreak. If the water supply is the cause it must be changed. All milk must be well boiled, and all possible sources of contamination must be investigated.

(*d*) The connections of cisterns, drains, water-closets, and sinks must receive careful attention, and all refuse, etc., must be removed at short intervals.

Cholera resembles typhoid fever in its manner of propagation being always produced either by contaminated water or food. It is an endemic disease in India and Central Asia, but in England it is a comparatively rare epidemic disease, having occurred on four occasions since 1831. The incubation period is short, averaging 2 or 3 days.

The infection is always spread by means of the vomit or bowel discharges from patients, and so there must always be complete and immediate disinfection of these. The precautions to be taken with regard to typhoid fever apply equally well for cholera, so it is needless to repeat them here.

Typhus Fever is essentially a disease of dirt, overcrowding, and underfeeding. It is therefore confined to the poverty-stricken quarters of large towns. During the past 30 years the death rate due to this disease has fallen from ·193 per 1000 to ·0066 per 1000, or about one-thirtieth of its former rate. As a matter of fact it is a disease which ought to have been banished from civilised communities before now.

The incubation period is very variable, the average being between 7 and 14 days. The infection is probably spread by the breath, but it is found that only the air immediately around the patient is infectious, as the germ is rapidly destroyed by fresh air, and does not cling to clothing. The essential preventive measures are particular attention to thorough ventilation, and personal cleanliness of the attendants. Cleanliness and fresh air, in fact, soon stamp out the disease.

ENDEMIC DISEASES.

Tuberculosis is a communicable disease produced by the tubercle bacillus. The lungs are the organs most frequently affected, the disease being then known as **consumption** or **phthisis**. The enormous mortality produced by this disease may be imagined from the fact that 11 out of every 100 deaths are caused by it. The direct cause of phthisis is undoubtedly the tubercle bacillus, but in order for it to successfully set up the disease it is probable that there must be one or more predisposing causes acting at the same time. A predisposition is usually acquired by a deficient supply of food and fresh air, or by prolonged illnesses. The predisposing causes may be divided as follows :—

(*a*) *Heredity*. Consumption is *not* hereditary. At the same time a predisposition *may* be inherited, so that it behoves people belonging to consumptive families to take extra precautions to prevent themselves being attacked.

(*b*) *Damp Soil*. It has now been established beyond the possibility of doubt that wetness of soil is a cause of the spread of phthisis to the population living upon it. In many districts the lowering of the level of the ground water by drainage has been immediately followed by a decrease in the death rate from consumption.

(*c*) *Overcrowding*, with consequent deficient ventilation is another potent factor in the cause of consumption. The best illustrations of this fact are obtained by reference to statistics comparing the mortality among large bodies of men in different barracks and prisons, where it appears to be inversely proportional to the amount of air space per head. An increase in the efficiency of the ventilation or in the cubic space allowed per head soon produces a decrease in the death-rate from consumption.

(*d*) *Occupation*. Working in close work-rooms, especially those where a large amount of gas is burned, is a further predisposing cause. Those occupations in which sharp particles of dust are inhaled, causing a chronic inflammatory condition of the lungs, render the workmen susceptible to the tubercle bacilli. Any exhausting occupation,

particularly when coupled with deficient supply of food, renders the body liable to invasion by the germs in question. Occupations necessitating an exposure to wet and damp may also be regarded as predisposing causes.

(*e*) Other predisposing causes are indulgence in alcohol, and exhausting diseases such as typhoid fever.

The dangers arising from the consumption of tuberculous meat and milk have already been alluded to. As a matter of fact the chief, and possibly the only, cause of infection is the dried expectoration from people suffering from the disease. As the sputum dries it rapidly becomes disseminated through the air in the form of dust and is inhaled by other people. On this account it is the duty of the authorities to devise some scheme whereby it may be made a punishable offence in trams, railway carriages, and public places. All affected persons should be compelled to spit into spittoons containing 10 per cent. carbolic acid solution, or the mouth may be wiped with rags which should be immediately burned. A consumptive patient should always be treated as infective, and must not under any consideration occupy the same bedroom as another person. Rooms used by consumptives need thorough disinfection after occupation by them. The methods of preventing consumption may be inferred by consideration of the above causes. They may be summarised thus:—

(1) Thorough ventilation of living-rooms, bedrooms, and workshops.
(2) Avoidance of injurious occupations, and the adoption of some out-door work.
(3) Nourishing wholesome food, containing a large proportion of fats.
(4) Disinfection of the sputum from infected cases, and of rooms after occupation by them.

The best treatment of incipient consumption is undoubtedly by wholesome food and fresh air. The "open air" treatment appears to be easily first from the point of view of results.

Scrofula is applied to an infection of the glands in the neck by tubercle bacilli. The invasion by the bacilli is

probably produced by the inhalation of air containing particles of dried sputum from a consumptive patient at a time when the throat is slightly inflamed and unable to resist their attack. From the throat they travel by the lymphatics to the glands where they multiply and produce the disease. As a rule only children in a generally low state of nutrition are affected.

Rickets is a diseased condition brought about by bad feeding, bad ventilation, and dark rooms. The commonest cause is the feeding of the child upon farinaceous and starchy "foods" which it is unable to digest properly, and which do not contain the necessary ingredients for the child's development. It is a general disorder, occurring mostly among the poor of overcrowded cities, but is occasionally seen among the offspring of the wealthy. The symptoms of a typical case are very characteristic. The ribs are beaded at the junction of the costal cartilages, and are somewhat altered in shape, while the sternum is protruded, causing the characteristic "pigeon chest."

The lower limbs are bowed, and showed enlargements of the bones near the joints. These swellings are often still more noticeable at the lower ends of the radius and ulna. The bony pelvis becomes distorted and deformed by the weight of the body in standing or sitting.

To prevent rickets the child should be brought up entirely upon milk, and the living-room and bedroom should be well lighted and well ventilated. When the disease has been developed the best treatment is to give plenty of fresh air, sunny rooms, and plain wholesome diet, mainly milk, cream, eggs, and cod-liver oil.

Rheumatic fever. There is every reason for believing that this is a disease produced by some unknown germ. It occurs with epidemic prevalence at irregular intervals of from 3 to 6 years, attacking both sexes at nearly every age. In Norway the disease is compulsorily notifiable by medical men. It has been recently proved by Dr. Newsholme that there is a very definite relationship between deficient rainfall, low ground-water, and high soil temperature on the one hand, and the prevalence of rheumatic fever on the other. The most constant exciting

causes are cold and damp, and these are found to be in operation in a large proportion of the cases. It is, no doubt, in accordance with this that it is least frequent in England in the months of July, August, and September. Patients who have suffered from an attack of rheumatic fever require particular care for several months in order to prevent or minimise the heart affections that may follow.

Malaria is now known to be caused by an organism or parasite which is communicated to men by a kind of mosquito. When in the blood these parasites pass through a definite cycle of development every 24, 48, or 72 hours according to the type of the fever. The soil, therefore, plays only a secondary part in the spread of malaria, by its favouring, or otherwise the life and development of this kind of mosquito. The most favourable conditions are the existence of pools of stagnant water containing water-weeds, because these are the breeding grounds of the insect.

The steps that may be taken to prevent malaria in a district are as follows :—

(*a*) The most efficient method is the draining of the soil. The lowering of the ground water is immediately followed by a decrease in malaria.

(*b*) The destruction of the eggs of the mosquito while in the pools. For this purpose petroleum may be used, as it acts mechanically by asphyxiating the larvae which float in the surface of the water.

(*c*) All pools and puddles should be filled in and drained, so as to leave no place where the mosquitoes may deposit their eggs.

(*d*) The inhabitants should protect themselves from the bites of mosquitos, especially at night, by mosquito curtains, and by inunction of the skin with oil or liniment containing camphor or eucalyptol.

The steps which are now being taken in malarious districts will probably end in the ultimate extinction of the disease.

APPENDIX.

Questions set at the Board of Education Examination in Advanced Hygiene.

Questions on Chapter I.

1888.—What are the methods for collecting and examining the suspended matters in the air?

1890.—Under what circumstances is carbonic oxide gas likely to be present in the air of rooms? What are its effects upon the human body?

1892.—How would you detect the presence and determine the amount of carbon dioxide in air?

1892.—What is the average rainfall in England? Mention the chief conditions influencing the rainfall of a place or country. How is rainfall calculated? What is the cause of rain?

1893.—How would you construct a rain gauge in the absence of a proper instrument? State the best position to place it.

1894.—How is the amount of water vapour in air determined, and how is it expressed? What influence has moisture upon health?

1894.—What is carbonic acid? What are its sources? How much is usually present in the outer air, and how is it estimated?

1895.—How do you know that air is a mechanical mixture of gases and not a chemical compound?

1897.—What impurities in air are caused by three manufacturing processes with which you are familiar? Explain how these can be best guarded against.

1898.—Describe in detail any method you would adopt to make a quantitative estimation of the oxygen in a given sample of air.

1899.—How can the amount of carbon dioxide present in the air of a room be determined?

1899.—How does the variation in the amount of aqueous vapour in the air affect the barometer? How is this aqueous vapour determined and expressed?

1899.—How is rainfall usually measured? Describe the construction of a rain gauge.

1900.—Describe the wet and dry bulb hygrometer. Explain how it is used to calculate the degree of humidity of the atmosphere.

1900.—What is ozone? How can its presence in air be best detected?

Questions on Chapter II.

1889.—What are the methods of ventilation by aspiration? State their advantages and disadvantages.

1893.—How much carbon dioxide is given off per hour by an average adult during (*a*) repose, (*b*) hard work? From each result calculate and show by means of an example the amount of air required hourly for an inhabited air space.

1894.—What is the composition of the atmosphere when fairly pure? Why does the air vary in density and volume at different elevations and temperatures? Explain what bearing these changes have on ventilation.

1896.—What is ventilation? Why is it necessary? How would you ventilate a schoolroom, and how much space would you allow to each pupil?

1897.—Explain how you would heat and ventilate a room without causing a draught.

1897.—What are the objects of ventilation? How much fresh air is required every hour for each adult, and why?

1898.—What is meant by the *diffusion of gases?* How does it affect the question of ventilation?

1899.—Describe in detail how you would determine the sufficiency of ventilation in a room.

1899.—Describe a system of ventilating an ordinary sitting-room, and explain how the change of air is effected. A room of 1000 cubic feet is occupied by one person; how often should the air be changed each hour?

1899.—State precisely how and to what extent air is vitiated by respiration. What are the methods of examining air for impurities?

1900.—What is the significance of organic matter in air? How does it affect the problem of ventilation, and how is the amount present usually determined?

1900.—Explain how the physical properties of air affect the question of ventilation. Illustrate your explanation by the action of a fire-place in a sitting-room.

Questions on Chapter III.

1884.—What amount of fat is contained in an average diet? How is it disposed of in the system? What are its effects on the intestinal canal?

1885.—Discuss the value of gelatine as an article of food. How much carbon and how much nitrogen are contained in an average diet?

1886.—Compare and contrast the various cereal grains as to composition and economical uses.

1888.—What are the most common adulterations of bread? How are they detected, and what is the importance of each?

1888.—How much lean beef, bread, butter, and water would be sufficient for an ordinary diet?

1889.—What are the quantities of food substances (proximate constituents) in the following diet? Lean Beef, 6 oz.; bread, 20 oz.; potatoes, 10 oz.; milk, 10 oz.; and water, 50 oz. Is it an economical diet or not?

1890.—What is the composition of lean beef? In what respects would a diet of 20 ozs. of lean beef and 30 ozs. of water be deficient?

1891.—How does margarine differ from butter in manufacture and composition? What amount of fat should be contained in a diet for laborious work, and what are its uses in the system?

1892.—What amount of proximate alimentary principles should be supplied in a diet for ordinary work? State the advantages of a mixed dietary.

1893.—What do you understand by the term "proximate alimentary principles"? State the amount of these principles necessary in a diet for (*a*) ordinary work, (*b*) hard work.

1894.—What are the functions of nitrogenous food? Mention the chief nitrogenous principles to be met with in food and their relative values as nutrients. How much nitrogen is required daily by an adult at ordinary work?

1895.—What are carbohydrates? State their general chemical composition. What are their uses in the body?

1895.—What is the general composition of fat, and how does it differ from that of sugar? What is meant by the digestion of fat; when and how does it take place?

1895.—How would you recognise wholesome and unwholesome butcher's meat? What diseases may be produced in man from the consumption of meat from diseased animals?

1896.—Explain the preparation of cheese. What is its value as an article of diet, and what is its average composition?

1896.—Life can be sustained longer on milk alone than on any other single article of food; explain the reason for this. Why is malted food good for very young children?

1897.—How is bread prepared? Explain its value as a food, and contrast its composition with that of cheese.

1897.—What is a standard diet? Give two examples of a simple meal containing all the constituents of food in about the right proportion.

1898.—What is the composition of beef? In what respects would a diet of 1 lb. of bread and 12 oz. of meat per day be deficient?

1899.—What are the essential constituents for a diet for ordinary work? Explain the functions fulfilled by each constituent, and how far one constituent may replace another.

1899.—Classify the various food stuffs, and explain their nutritive functions.

1899.—What is the composition of butter? Mention the common adulterations.

1900.—What amounts of proteids, fats, and carbohydrates are required in a standard diet for ordinary work? Calculate the amount

of lean meat, butter, and bread which would be required to produce these proximate principles.

1900.—What is the composition of cow's milk? How can adulteration be detected?

Questions on Chapter IV.

1888.—What impurities are most likely to be found in aerated waters, and what is their importance?

1893.—What is the composition of beer? From what and how does it derive its intoxicating properties?

1894.—Describe the process of brewing and the theory of fermentation.

1895.—What are aerated waters? What impurities are they likely to contain, and why?

1898.—Give a brief description of the English method of brewing beer, and explain how it differs from the process adopted in Bavaria and Germany. How can the percentage of alcohol be determined?

Questions on Chapter V.

1884.—In what articles of clothing and of decoration is arsenic sometimes found? What are its injurious effects, and under what circumstances are they likely to appear?

1884.—What is meant by hereditary tendency? What diseases are most markedly hereditary? What precautions should be taken against hereditary disease?

1887.—What is the best position for writing? What are the advantages of this position?

1889.—How much air-space and how much floor-space per head would you provide for in a schoolroom? How would you arrange the lighting?

1890.—Describe, stating your reasons, the school furniture you consider best adapted for young children.

1891.—How is "short sight" produced in school children? What measures are necessary to prevent it in schools?

1892.—What are the advantages of woollen clothing? Explain its action in preventing chill.

1895.—What is the difference between a wool and a cotton fibre? Contrast the advantages and disadvantages of wool and cotton clothing generally.

1897.—What are the most important points to be borne in mind in the construction and wearing of clothing?

1897.—Explain the influence of age, sex, and heredity in the causation of disease.

1897.—Why do children need to be well clothed? Explain the important points to be borne in mind in constructing clothing generally.

1898.—What are the comparative advantages of cotton, linen, and wool for underclothing?

1899.—Explain why warm clothing is so necessary in the case of young children. Compare the advantages of wool and linen as a material for underclothing.

1900.—What special precautions should be taken as to the clothing of young children and old people?

1900.—What materials are most suitable for clothes in cold weather?

Questions on Chapter VI.

1885.—What methods should be adopted for preventing (*a*) moisture, (*b*) air from the soil, from entering a house, and why should they be excluded?

1887.—What are the advantages and disadvantages of the different ways of covering the walls of rooms?

1895.—What are the principles which should guide us in constructing house foundations and basement floors? How are these best carried out?

1896.—Contrast the sanitary advantages and drawbacks of the following materials for roof coverings: slates, Broseley tiles, zinc, lead.

1897.—Describe the mode of constructing house walls and floors so as to prevent damp.

1898.—What is the composition of ground-air? On what conditions are its movements dependent? Describe the steps which should be taken to prevent its entry into a dwelling-house.

1899.—State the best position for a "damp-proof course" in walls and name the various materials in general use; give a careful description of the method of construction you prefer.

1900.—What are the best materials for (*a*) the floor of a sitting-room, and (*b*) the floor of a kitchen?

1900.—What are the chief materials used in the construction of roofs of dwelling-houses? Compare their relative advantages.

1901.—Explain what is meant by a damp-proof course, and describe how it should be constructed.

Questions on Chapter VII.

1886.—Describe some stoves with arrangements for the admission of warmed fresh air into rooms; give a sketch of one of them.

1889.—Describe in detail a grate or stove provided with an arrangement for the introduction of warm fresh air.

1892.—Explain the principle of construction of an ordinary fire-place, and state its advantages and disadvantages.

1894.—Describe the principle upon which hot water is generally supplied to bathrooms, etc., and explain the reason why such an arrangement may be attended with danger. How can this be avoided?

1895.—On what principles should fireplaces be constructed? Explain their advantages and disadvantages as a means of heating rooms as compared with hot-water pipes.

1896.—What are the objections to stoves as means of heating dwelling-rooms? Describe any two forms with which you may be familiar, and point out their respective advantages and disadvantages.

1898.—Describe a method of warming a building by means of low pressure hot-water pipes.

1898.—Contrast the advantages and disadvantages of heating a building:

(*a*) By hot-water pipes.
(*b*) By closed coke stoves.
(*c*) By open fireplaces.

1899.—What are the respective advantages, disadvantages, and dangers (if any) attendant upon the use, for warming rooms, of (*a*) open fires, (*b*) slow combustion, (*c*) closed coke stoves, (*d*) gas stoves, and (*e*) hot-water pipes?

1900.—What are the advantages and disadvantages of stoves? Describe a good form of ventilating stove.

1900.—Explain in detail (with sketch) one method of supplying a house with hot water.

Questions on Chapter VIII.

1884.—Describe the construction of a "pan" water-closet, and of a "D" trap, giving sketches. Are they good or bad forms of sanitary apparatus? Give your reasons.

1886.—Sketch and describe a good form of hopper water-closet. How should it be supplied with water?

1888.—What points should be attended to in the construction of a house-drain?

1889.—What are the uses of soil-pipes? How should they be constructed, ventilated, and connected with the house-drain? Illustrate your answer by sketches.

1890.—Describe, with sketches, some simple forms of water-closet basins and traps, stating which you prefer and why.

1891.—How should a house-drain be constructed, ventilated, and disconnected from the public sewer? Give a sketch.

1892.—What means would you adopt to prevent the entrance of sewer-gas into a house?

1893.—Describe and illustrate by means of a diagram a good and bad form of water-closet. Explain its proper connection with any system of drainage.

1895.—Describe the construction of a good and a bad water-closet, illustrating your answer by a sketch. State their respective advantages and disadvantages.

1896.—What forms of water-closet are most suitable for labourers' dwellings and for factories? Under what conditions may they be expected to work satisfactorily?

1897.—What is a soil-pipe? Explain how it should be constructed and connected with the house-drain. Illustrate your answer by sketches.

1897.—Describe briefly the essential points to be observed in the construction and arrangement of water-closets for a house.

1898.—What are the important points as regards the materials, construction, dimensions, positions, and course of a soil-pipe? Give your reasons for considering them important.

1898.—Sketch (and explain your diagram) a good form of water-closet with its fittings and connections. What should be the diameter of the supply pipe and of the soil-pipe, and what amount of water should be supplied for each flush of the closet?

1899.—Give sketches of some of the principal water-closets in common use. Mention their advantages and disadvantages.

1900.—What is meant by *siphonage*? Explain how it affects the working of water-closets and how it may be guarded against.

1900.—What is the difference between a slop-sink and an ordinary sink?

1901.—Sketch the arrangements for the drainage of a two-storeyed house, including water-closets, bath, and sink, and show the connection between the house-drain and the sewer.

Questions on Chapter IX.

1884.—What are the advantages and the disadvantages of the water carriage system of excrement removal?

1887.—What are the best known chemical methods for the treatment of sewage? How far are they successful?

1890.—Give a short account of the treatment of town sewage by a precipitation process, stating the results you would expect.

1892.—Describe the method of dealing with excreta by means of dry earth, and state the action of the earth upon the excreta. What points are essential to its success?

1895.—How should a cesspool be constructed? Describe under what circumstances it should be used, and the arrangement you would make for its connection with the house. If possible, illustrate your answer by a sketch.

1893.—Define the terms "Intermittent downward filtration" and "Irrigation" as used in the disposal of sewage. What are the conditions to ensure success in both of these methods?

1898.—What are the comparative advantages of the "dry" and "wet" methods of sewage disposal? Describe in detail one system of dry removal.

1899.—What do you understand by the "biological methods" of treating sewage?

1900.—Describe a good form of joint for sewers which have to be laid in a water-logged soil. How should sewers be ventilated?

Questions on Chapter X.

1885.—What is the constant system of water service? What are its advantages, and what dangers may be apprehended from its adoption?

1886.—What are the materials used for filtering water on the small scale? How do they act? What points should be attended to in the construction of a domestic filter?

1888.—Describe the construction and action of an arrangement for filtering water on a large scale.

1889.—Describe the intermittent system of water service. What are its advantages or disadvantages as compared with the constant system?

1890.—What are the various methods for purifying water on a small scale for domestic purposes?

1892.—Describe the action of charcoal as a filtering medium for water. What are its advantages and disadvantages?

1893.—What is the object of filtering water? Describe any form of filtering material with which you may be familiar, and state what chemical action it has upon water.

1894.—What action has water on lead pipes? What quantity of lead dissolved in water is poisonous, and how would you detect its presence?

1896.—Explain the various ways in which drinking water may become contaminated within a dwelling, and mention the means to be adopted for preventing such contamination.

1896.—What waters have (*a*) the greatest and (*b*) the least action on lead? What conditions favour their plumbo-solvent action?

1897.—Enumerate the chief sources of water supply, and point out in respect of each the chief impurities likely to be met with.

1897.—How may drinking water be contaminated in a dwelling-house after delivery? Explain the precautions to be taken to guard against this contingency.

1898.—Describe any one form of filter with which you are acquainted, and explain its action on water.

1898.—What methods would you propose for the purification of a domestic water supply? Discuss the value of the various filtering media in general use.

1898.—What are the characteristics of river water, and what are the dangers attending its use?

1898.—Describe, in detail, a method for the filtration of river water on a large scale, and the results produced by it. Discuss the advantages and disadvantages of rivers as a source of drinking water.

1899.—Describe a sand filter for use on a large scale, and explain its action.

1899.—What waters have the greatest solvent action on lead? How can the action be prevented?

1900.—Describe in detail the method of constructing an impounding reservoir.

1900.—What do you understand by germ-proof filters? Describe one in detail and explain its action.

Questions on Chapter XI.

1887.—What precautions is it necessary to take to prevent the spread of enteric (typhoid) fever?

1889.—What are the causes of rheumatic fever? What are its dangers? What precautions should be taken during convalescence?

1890.—Compare and contrast the methods for preventing the spread of typhus and typhoid fevers.

1891.—What are the distinctions between disinfectants, antiseptics, and deodorants? Give examples of each. How should infected bedding be purified?

1892.—What are the conditions that favour the propagation of consumption? What means can be adopted for its prevention?

1893.—How is small-pox propagated? What remedies would you propose for its prevention and ultimate extinction?

1894.—How is diphtheria propagated? To what is attributed the recent increase of this disease in towns, and what remedies would you propose for its prevention?

1894.—What steps would you take for the purification of a school-room in which several cases of diphtheria had occurred?

1895.—What precautions should a community take for the prevention of the spread of infective diseases?

1895.—What are the usual sources of infection in enteric or typhoid fever? Explain the precautions you would take to prevent its extension.

1896.—What are the causes of scrofula and rickets? In what class of the community are these diseases most common, and what principles should be observed to prevent their excessive prevalence?

1897.—Explain the difference between a disinfectant and an antiseptic, giving examples of each. How would you disinfect books, pillows, and bed-sheets?

1897.—What is meant by an infectious disease? Give two examples, and detail the chief precautions to be taken when an infective fever occurs in a house.

1899.—What are the best means for disinfecting clothing? Define the terms "superheated" and "saturated" steam, and state what advantages the latter has (if any) over the former method.

1899.—What do you understand by a disinfectant? Explain the difference between saturated and superheated steam.

1900.—What preventive measures should be taken to prevent the spread of scarlet fever in a small town?

SPECIMEN EXAMINATION PAPERS.

Evening Examination, 1901.

Six Questions may be answered.

1. Draw up a typical dietary for a healthy man doing heavy manual labour. Show why each item is essential. (34)
2. What dangers may arise from an intermittent water supply? (34)
3. Show how the amount of (*a*) carbonic acid gas and (*b*) organic matter can be estimated in a sample of air. (33)
4. Explain what is meant by a damp-proof course, and describe how it should be constructed. (34)
5. Explain how the waste-pipe from a bath should be connected with the drain, and how danger to health may arise. Illustrate your answer with a sketch. (33)
6. What are the chief principles to be observed in the construction of house-drains? (34)
7. How does the amount of moisture in the air influence health? How is it calculated? (34)
8. Describe two different types of domestic filters, and explain their action. (33)
9. State what you know of any measures that can be adopted to prevent malarial disease in a district. (34)

Day Examination, 1901.

Six questions may be answered.

1. What food stuffs must be present in a diet to maintain health? Explain the functions of each. (32)
2. What is the composition of beer? How is it usually adulterated? (32)
3. What action has water on lead pipes? What quantity of lead dissolved in water is considered poisonous, and how would you detect its presence? (32)
4. What is the composition of pure air? How is it that air varies in density and volume at different elevations and temperatures? Explain the relation of their changes to natural ventilation. (32)

5. What do you understand by the "biological" treatment of sewage? Describe briefly one method proposed. (32)

6. What do you understand by the term "disinfectant"? Explain some of the latest methods proposed for the disinfection of rooms. (32)

7. What is the cause of rain? How is it usually estimated, and what is the average annual amount in England? (32)

8. What is the influence of schools on the propagation of diphtheria and scarlet fever? (32)

Evening Examination, 1902.

Six questions may be answered.

1. What do you understand by the term "proximate alimentary principles"? State the amount of these principles necessary in a diet for (*a*) hard work; (*b*) ordinary work. (34)

2. What action has pumping water from a well, on the curve of underground water? How can a well be protected from surface pollution? (33)

3. What is the composition of cheese? What is its value as an article of diet? (33)

4. What do you understand by (*a*) a closed stove, and (*b*) a ventilating stove? How does the mode of conveyance of heat from these stoves differ from that from a fireplace? (34)

5. Sketch the arrangements for the drainage of a two-storied house, including water-closets, bath, and sink, and show the connection between the house-drain and the sewer. (33)

6. What do you understand by the following terms:—*Current*, *Confined*, *Saturated*, *Superheated* steam?

What form of disinfector would you recommend for (*a*) a large manufacturing town; (*b*) a poor rural district? Give your reason for the selection. (33)

7. What are the impurities, (*a*) gaseous, (*b*) solid suspended, found in the air of inhabited rooms? How can you determine the presence of these impurities in air?

8. What methods would you propose for the purification of a domestic supply? Discuss the value of the various filtering media in general use. (33)

9. What preventive measures should be taken to prevent the spread of phthisis? (33)

Day Examination, 1902.

Six questions may be answered.

1. Describe some of the methods of preserving meat. (33)
2. Compare the filtering action of a Pasteur-Chamberland, and a large sand filter. How can the work of these filters be kept under control? (34)
3. What objection is there to rooms above 12 or 14 feet high, from the point of view of ventilation? (33)
4. How should a cesspool be constructed, and what distance should it be from the house? (33)
5. What are the chief methods of warming by hot-water pipes? (34)
6. How is the amount of moisture in the atmosphere usually determined? What is the average humidity of the air in this country? (33)
7. Describe the best method of lighting a school-room? How should the desks be arranged? (33)
8. Describe the dry-earth system for the treatment of excreta, and point out its advantages and disadvantages. (33)
9. What are the advantages and disadvantages of formalin when used to disinfect a room? How is it best applied? (34)

INDEX.

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